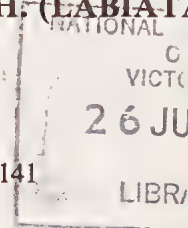


A TAXONOMIC REVISION OF *PROSTANTHERA* LABILL. SECTION *KLANDERIA* (F.v. MUELL.) BENTH. (LABIATAE)

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Abstract

A taxonomic revision of *Prostanthera* section *Klanderia* is presented. General chapters on taxonomic history, morphology, pollination, and breeding systems precede the systematic treatment. Fifteen species are recognized of which eight are described for the first time. The new species are *P. florifera*, *P. incurvata*, *P. laricoides*, *P. monticola*, *P. patens*, *P. pedicellata*, *P. porcata* and *P. semiteres*. Two subspecies of *P. serpyllifolia* and two subspecies of *P. semiteres* are recognized. *P. semiteres* spp. *intricata* is described for the first time. Keys to the species and subspecies are provided. All recognized taxa are provided with full descriptions, distribution information (including maps), ecological and other relevant notes. All species are illustrated.

Morphological variation of *P. aspalathoides*, the *P. calycina*-*P. microphylla*-*P. serpyllifolia* complex, and the *P. laricoides* complex, plus the volatile leaf oil variation of *P. aspalathoides*, were investigated using the multivariate numerical techniques: canonical variate analysis, principal components and principal factor analyses, principal coordinates analysis, surface trend analysis (contour mapping) and differential systematics.

Patterns of variation appeared to be associated with environmental and historical factors in *P. aspalathoides* and in the *P. calycina*-*P. microphylla*-*P. serpyllifolia* complex. The distinctness of the Kangaroo Island populations appears to reflect the relatively long separation of this island from the mainland.

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Introduction

Prostanthera species are evergreen sub-shrubs, shrubs or small trees (*P. lasianthos*) with decussate leaves, racemiform inflorescences, two-lobed calyces, four fertile two-celled anthers in each flower, terminal styles, and fruits composed of four mericarps. *Prostanthera*, with *Eichlerago*, *Hemiantra*, *Hemigenia*, *Microcorys*, *Westringia* and *Wrixonia* are grouped together in the subfamily Prostantheroideae of the Labiatae (Briquet 1895; Melchior 1964; Carrick 1976, 1977). Carrick (1977) offered a diagnosis for Prostantheroideae. His early paper (Carrick 1976) summarizes the key differences between all the genera in the subfamily (with the exception of *Eichlerago* which was not described at that time). The results from the work of Sharma & Singh (1982) on carpel morphology (refer pp. 219 & 220) require Carrick's diagnosis of the Prostantheroideae to be modified to:

Stamens 4 or only 2 (adaxial or abaxial pair sterile); style terminal (may superficially appear subgynobasic); fruit of 4 separate mericarps or entire, dry and indehiscent (*Eichlerago*).

Comment on generic delimitations within the Prostantheroideae must await critical evaluation which is beyond the scope of this present study.

The Prostantheroideae are endemic to Australia with the most disjunct distribution being recorded by Jacobs & Pickard (1981) for *Westringia fruticosa* which they list as occurring on Lord Howe Island. Furthermore, this subfamily is the only one (of the Labiatae) in which any genus is endemic to Australia (Jessop 1980). The Prostantheroideae appear to be a distinct taxon of the Labiatae. This is indirectly verified by the fact that the Prostantheroideae, as circumscribed by Bentham [as 'Tribus VII. Prostanthereae.' (Bentham 1834, p. 447); and Bentham & Hooker 1876], has been maintained almost unaltered by subsequent authors. Cunningham recognized the homogeneity and distinctness of the group of genera which are now classified within this subfamily as early as 1825 (Cunningham, in Field 1825). However, prior to 1834 the genera which are now regarded as belonging to the Prostantheroideae were frequently placed in separate infra-familial groups (e.g. Reichenbach 1828; Bentham, in Lindley 1829-1830; Bartling 1830). Without evaluating the relationship between the subfamilies of the Labiatae, workers have

usually regarded the Prostantheroideae as most closely related to the Ajugoideae (e.g. Briquet 1895; Hillson 1959).

The Prostantheroideae, together with the Ajugoideae and Rosmarinoideae, are regarded as transitional subfamilies between the remaining Labiatae and Verbenaceae (Cronquist 1981). The relationship between these two families and the general affinities of the Lamiales are discussed by several authors (Cantino 1982; Carrick 1977; Cronquist 1981; Munir 1978 and Thorne 1976).

During preliminary non-numerical taxonomic and ecological studies of *Prostanthera* section *Klanderia*, several taxonomic problems were recognized. It was noted that certain taxa had patterns of character variation which appeared to be very complex. Furthermore, some of these taxa appeared to intergrade such that it was difficult to distinguish between them. The taxa which make up the complexes (*P. aspalathoides*, *P. calycina*, *P. serpyllifolia* and the *P. laricoides* complex [including synonyms—refer 'Systematic Treatment']) were subsequently examined in detail so that various biometrical analyses could be carried out in an attempt to simplify and visualize any underlying distribution pattern within these taxa. The results of the various analyses (refer 'Numerical Analysis') were used to suggest and to test hypotheses related to the relationship between the taxa. The information

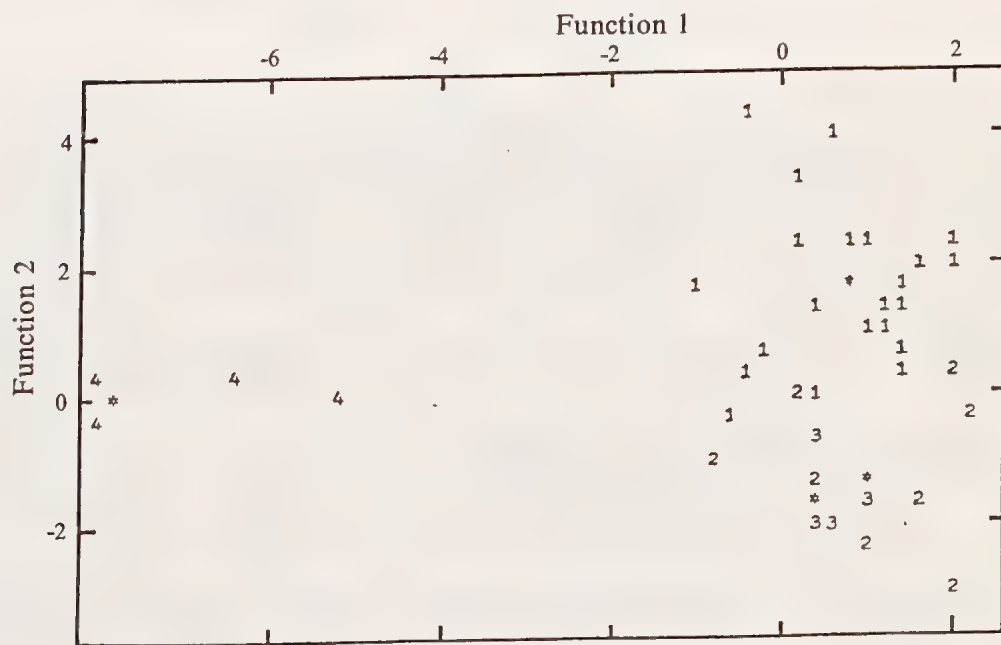


Fig. 1 Canonical variate scattergram (function 1 versus function 2) of the volatile leaf oils of *Prostanthera*. 1 = *Prostanthera* sect. *Prostanthera* series *Racemosae*; 2 = *Prostanthera* sect. *Prostanthera* series *Convexae*; 3 = *Prostanthera* sect. *Prostanthera* series *Subconcavae*; 4 = *Prostanthera* sect. *Klanderia*; * = group centroid.

provided then formed a basis for the construction of a taxonomic classification scheme. Other taxa could be evaluated and distinguished using non-numerical taxonomic procedures because they were significantly distinctive.

The geographic variation found in *P. calycina*, *P. serpyllifolia* and *P. laricoides* was studied using morphological features as taxonomic characters. In *P. aspalathoides* the geographic variation was studied using both morphological and volatile leaf oils (terpenoids) as taxonomic characters. The results of these analyses were used to test hypotheses related to the relationship between these taxa and environmental factors.

Without undertaking a critical evaluation of Benthams infrageneric classification (refer 'Taxonomic History'), section *Klanderia* appears to represent a natural group. As pointed out by Benthams (1870), 'the shape of the corolla is so different from [that of section *Prostanthera*] . . . that this section might well be considered as a distinct genus . . .'. Other morphological characters (refer pp. 285-341) and, to some extent, its distribution (compared with that of sect. *Prostanthera*) support the distinctness of this section. A canonical variate scattergram (function 1 versus function 2) of the volatile leaf oils of 38 species is illustrated in figure 1. This canonical variate analysis was based on 64 specimens (50 from Lassak 1980, tables 4-6; 14 from personal collections). Within the limits of the data, a consideration of the volatile leaf oils also suggests that sect. *Klanderia* is distinct from sect. *Prostanthera*. Since sect. *Klanderia* appears to represent a distinct group within the genus, Benthams sectional subdivision of *Prostanthera* is here accepted (Benthams 1870). A critical re-evaluation of Benthams subdivision of sect. *Prostanthera* is premature until the whole genus is revised. However, the canonical variate scattergram (Fig. 1) suggests that series *Racemosae* is distinct from the other two series, whereas series *Convexae* and series *Subconcavae* are less distinct from each other (at least on the first two functions).

Taxonomic History

Prostanthera was described in 1806 by Labillardière for *P. lasianthos*, a species from eastern Australia (Queensland, New South Wales, Victoria and Tasmania). Since then, a number of publications (e.g. Benthams 1834; Brown 1810; von Mueller 1868) have made significant contributions to our present understanding of *Prostanthera* Labill. However, the two most significant contributions on infrageneric concepts are those of Benthams (1870) and Briquet (1895).

While there has been general consensus on generic concepts, there has been less agreement on the subdivision of the genus. Benthams (1870) was the first to subdivide the genus into sections (sect. *Prostanthera* [as sect. '*Euprostanthera*'] and sect. *Klanderia*). These sections were largely based on floral characters (refer pp. 285, 286). He further subdivided section *Prostanthera* into three series (viz. series *Racemosae* [including the generic type, *P. lasianthos*], series *Convexae* and series *Subconcavae*). These series were based on the position of the inflorescence, the type of bracts, and the shape of the leaves (Benthams 1870, pp. 91 & 92).

Moore (1893) subdivided the genus into two sections (viz. section I [=sect. *Prostanthera*] and section II [=sect. *Klanderia*]). He further subdivided section I into two groups (viz. undersection I [=series *Racemosae* Benth.] and undersection II [=series *Convexae* Benth. and series *Subconcavae* Benth.]).

Briquet (1895) subdivided the genus into three sections (viz. sect. *Depremesnilia* [as sect. '*Depresmenilia*'—typographical error], sect. *Cryphia* [=sect. *Klanderia*], and sect. *Prostanthera* [as sect. '*Euprostanthera*']). *Prostanthera chrysocalyx* (F. v. Muell.) Briq. [= *Depremesnilia chrysocalyx* F. v. Muell., type species of sect. *Depremesnilia* (F. v. Muell.) Briq.] was transferred to *Pityrodia chrysocalyx* (F. v. Muell.) Gardner (Chloanthaceae) by Gardner (1931). For further details refer Munir (1978, 1979).

Bentham chose von Mueller's generic name *Klanderia* as a sectional name, over the earlier name *Cryphia* (of R. Brown), because the latter name was derived 'from a character probably abnormal in the particular flower examined' (Bentham 1870, p. 105). Briquet (1895) chose *Cryphia* as the sectional name, presumably because it is the earlier generic name. However, since generic names do not have priority outside their own rank (Stafleu *et al.* 1978: Art. 60), Bentham's sectional name must be followed.

Briquet (1895) accepted Bentham's (1870) subdivision of sect. *Prostanthera* into series.

In 1970 Carrick began a revision of the genus. Only two publications (Carrick 1976, 1977) on related genera were completed before his death in 1978. He published a key to the recognized species of *Prostanthera* in Althofer (1978) and his contribution to the more formal taxonomic aspects of this book appears to be considerable. Unfortunately, he apparently had not finalized his concept of the genus. There is no manuscript and his occasional brief notes are insufficient to formulate any appreciation of his concepts in *Prostanthera*.

Approximately eighty species have been described, all from Australia. Nelson (1981) listed 60 previously described species of *Prostanthera* which were recognized by Carrick. However, he incorrectly cited the number of species for Tasmania as 19 (with 17 endemics). Carrick (Barker, *in litt.*) actually recognized 3 species (with no endemics) for Tasmania. In addition to those listed in Nelson (1981), Carrick (Barker, *in litt.*) recognized 37 species for New South Wales (of which 19 are endemic) and 10 species for Queensland (of which 6 are endemic).

Methods, materials and presentation

The measurements of the morphological characters (for both numerical and non-numerical analyses) and the descriptions of all taxa were made from herbarium specimens. 605 specimens (Conn 1982, pp. 258-264) were used in the various biometrical analyses. Some of these specimens were replicate samples from the same individual whereas others were replicate samples from local populations. The quantitative and qualitative values of the various characters (for each individual) as used for the numerical analyses, are the average of five separate observations. Although Blackburn (1980) pointed out the inadequacy of using mean character values as a measure of resemblance, particularly when character states overlap considerably between taxa, his method was not used because his data standardization procedure requires quantitative data to be grouped into a fixed number of class intervals (usually 8). Furthermore, the necessity to set class boundaries is regarded as inappropriate.

The descriptions were supplemented by personal field observations. In the descriptions, those character states which occur in one or a few specimens (hence, occur in fewer than 10% of the individuals in the relevant taxon) are enclosed by parentheses. Parentheses are also used to enclose rarely occurring character states which may be present in an otherwise typical individual specimen. No distinction is made between these two situations.

In general, usage of terms follows Lawrence (1955), Porter *et al.* (1973), and Stearn (1973). Terminology for plane shapes follows Ball *et al.* (1962). Author and literature abbreviations follow Stafleu & Cowan (1976, 1979, 1981). English nomenclature for Australian birds follow Schodde *et al.* (1978). I found that it was only necessary to recognize formally one level of variation within any single species. Therefore the proposal of Raven *et al.* (in Raven 1974) and the example of *Flora Europaea* (refer Tutin *et al.* 1964) to use 'subspecies' as the only infraspecific category was followed in this treatment.

Although I began my revision of *Prostanthera* in 1979, most of the herbarium material of this genus had been on loan to the State Herbarium of South Australia (AD) since 1972/73. Collections on loan from the British Museum (BM) were returned, upon request,

before many taxa were fully considered. In a number of cases this has prevented typification. I was reluctant to endanger the material further by requesting an additional loan of the relevant collections so soon after their return.

The distribution of each taxon is briefly summarized after its description. The distribution summary and the selected citation of specimens examined are grouped according to various regional subdivisions. The regional subdivisions that I have used for the States are: for Queensland I have followed the pastoral divisions used by the Queensland Herbarium (BRI) [as in *Contr. Queensl. Herb.* 19 (1975) back end paper], for New South Wales those of Jacobs & Pickard (1981) (which is modified from Anderson 1961), for Victoria those of Cochrane *et al.* (1968), for South Australia those of Laut *et al.* (1977a, 1977b, 1977c, 1977d), and for Western Australia those of Beard (1980).

The conservation status of each taxon is provided (as stated by [Conn in] Leigh *et al.*, 1981 or using the formulae of Leigh *et al.*, 1981).

The ecological notes are taken from collector's notes on the labels of herbarium sheets, supplemented in most cases by personal field observations.

Common names are included where known.

Herbarium abbreviations are those given in Holmgren *et al.* (1981). Since Kings Park and Botanic Gardens (West Perth, Western Australia) is not listed in 'Index Herbariorum', collections examined from this herbarium are referred to as 'KP'. Collections from the following herbaria were examined: A, AD, ADW, BM, BR, BRI, C, CANB, CBG, E, F, GH, GOET, HAL, HBG, HO, K, KP, L, LD, LE, LY, M, MEL, MO, NE, NSW, NT, NY, P, PERTH, S, SYD, UC, UP, US, W, WRSL, WU.

Herbarium material was studied at the State Herbarium of South Australia (AD), numerical analyses were carried out in the Botany Department of the University of Adelaide, and preliminary gas-liquid chromatographic analyses were carried out in the Organic Chemistry Department (University of Adelaide). The detailed gas-liquid chromatographic analysis of the volatile leaf oils of *P. aspalathoides* (as presented in this study), was carried out at the Biological and Chemical Research Institute, Rydalmere (N.S.W.).

Selected morphological characters

In this chapter a detailed discussion of various morphological structures, including the extent of morphological variation in sect. *Klanderia* is provided. Those characters which have been employed in the taxonomy of the group or those which are of potential taxonomic value are given particular emphasis. The definitions of terms which are used later in this revision are also provided.

Habit

All axes of the sub-shrubs or shrubs of *Prostanthera* sect. *Klanderia* have continuously active meristems. The plants are architecturally differentiated into a primary axis ('stem') and equivalent branches. Branching appears to occur more or less continuously. This shoot construction is referable to Attim's architectural model (Hallé *et al.* 1978). Periodicity of growth appears to be induced by seasonality and apparently is not endogenous.

The primary axis is frequently damaged. In such instances, adjacent lateral axes may 'replace' the primary one. If the primary axis of young plants is damaged, it may be very short, such that the usually many-branched, mostly erect small shrub appears to be multi-stemmed. The lower branches usually develop at or just above ground level. Some species form densely branched compact shrubs (a common habit form of *P. aspalathoides*),

whereas others have fewer branches and an open habit (e.g. *P. chlorantha* and *P. patens*). *P. walteri* has a habit of tangled branches, especially in exposed situations. Semi-prostrate to prostrate forms are found in coastal forms of *P. serpyllifolia* (e.g. at Innes National Park and Cape Cassini, South Australia), and in the subalpine species *P. walteri* and *P. monticola*. The habit is modified by salt-pruning in *P. serpyllifolia*, but in the latter two species it is caused by extremely low temperatures associated with the ice and snow. In more sheltered situations, these three species have the more typical semi-erect to erect habit.

In *P. chlorantha* shoots occasionally arise (Conn 685) from horizontal stems that are either on or just below the soil surface.

Indumentum

Both glandular and non-glandular trichomes are present. Non-glandular trichomes are here referred to as 'hairs' (refer descriptions in 'Systematic Treatment'), whereas glandular trichomes are referred to as 'glands'. Therefore, the various parts of a plant are described as glabrous or hairy (with reference to the non-glandular trichomes), irrespective of the presence or absence of glands.

The glandular trichomes ('glands') are more or less hemispherical (typical of those in many members of the Labiatae, cf. Uphof 1962, Fig. 55) and are particularly common on the distal parts of branches, on the outer surface of the calyx, and on the pedicel.

The non-glandular trichomes ('hairs') occur on most parts of the plants. *P. pedicellata* and *P. semiteres* have glabrous branches and leaves. However, all other species have some hairs on the vegetative parts. The hairs of the branches are frequently denser along two narrow zones (each on opposite 'sides' of the branches which extend from the leaf axil region to the next more distal nodal region between the opposite leaf bases). The hairs tend to be denser on the distal (juvenile) portions of the branches. The hair density of the branches, as recorded in the descriptions, was measured from the second to fifth distal internodes.

The leaves are usually more densely hairy on the abaxial surface than adaxially. Frequently the hairs are restricted to the midrib region of the abaxial surface and/or to the base of the leaf.

The pedicel, margin of prophylls, and the outer surface of the calyx and corolla (particularly on the respective lobes), are frequently hairy. The inner surface of the calyx is glabrous in most species. However, *P. incurvata*, *P. laricoides*, *P. patens*, *P. pedicellata* (usually), and *P. semiteres* (in this study all of these species are referred to as part of the *P. laricoides* complex of Western Australia) are hairy on the inner surface of the calyx. Sometimes these hairs are restricted to the distal positions of the calyx lobes.

The indumentum is usually more or less tomentose, sometimes becoming pilose. The hairs are more or less patent basally and recurved to reflexed distally, such that the hairs often appear curled. The hairs of *P. calycina* are appressed and are not curled. Furthermore, they are relatively long (up to 0.5 mm long) and stiff. Most species have simple one-celled hairs, however *P. chlorantha* (Fig. 54) and the Kangaroo Island populations of *P. serpyllifolia* ssp. *microphylla* have irregularly branched, multi-celled hairs similar to those of *Lavandula officinalis* (Hummel & Staesche 1962, Fig. 8).

The density of hairs, particularly on the branches, is in general extremely variable and of little taxonomic value (e.g. refer *P. semiteres*, p. 112). The juvenile portions of the branches are usually relatively densely hairy. These hairs tend to be lost from the older branches. If plants were collected during growth-limiting conditions the amount of new growth would be very small and so, a low hair density would be recorded.

Therefore, the density of hairs (on branches), as recorded in this study, may indirectly reflect the seasonal climatic conditions prior to the time of collection.

Leaves

The leaves of all species are decussate. They are more or less terete (often slightly compressed) in *P. aspalathoides*, *P. florifera*, *P. incurvata*, *P. laricoides*, *P. pedicellata*, and *P. semiteres*. All of these species have leaves which are narrow and more or less oblong to obovate (for details refer relevant species description in 'Systematic Treatment'). The petiole of these species is very short or absent. All remaining species usually have distinct, but often short-petiolate leaves. Ovate to suborbicular leaves are found in *P. chlorantha*, *P. patens*, *P. serpyllifolia* ssp. *microphylla*, and occasionally in *P. ringens*. Normally, the leaves of *P. ringens* and *P. serpyllifolia* ssp. *serpyllifolia* are more or less flat and oblong to obovate. *P. monticola*, *P. porcata* and *P. walteri* have the largest leaves (for the section) which are relatively broad. *P. grylloana* has spatulate conduplicate leaves.

The leaf margin is frequently recurved, except for those species with more or less terete leaves. In many instances the recurvature of the margin is, at least in part, a response to water stress and so, is probably of dubious taxonomic value. The leaves of *P. grylloana* appear to respond to water stress by becoming strongly conduplicate, thus reducing the exposed adaxial surface area of the leaf.

The lamina shape, size, and other features (as discussed above), are frequently useful supplementary characters, particularly for verifying initial determinations.

Inflorescence

Carrick (in Althofer 1978) and all previous workers have regarded the inflorescence of section *Klanderia* as lateral (axillary), with each inflorescence being a single flower. A detailed re-evaluation of the structure of the inflorescence is not possible until all genera in the subfamily Prostantheroideae have been examined. However, it is possible to give brief tentative interpretations of the inflorescence structure for the genus.

Architecturally, the inflorescence of the species in section *Klanderia* is pleoanthic (*sensu* Hallé *et al.* 1978) since flowering usually coincides with shoot expansion. All floral [=flower-producing] axes end in non-floral buds [hence \approx indeterminate] (Fig. 2). Briggs and Johnson (1979) regard this structural type as blastotelic [\approx polytelic, Troll 1964 & 1969] and since the R_z axes (refer Fig. 2) continue to grow beyond the flowering region, they are auxotelic.

Since the prophylls (Fig. 2B) are closely associated with the developmental sequence of the flower, the ultimate 'internode' is thought to represent the last infrafloral region. In the Myrtaceae Schmid (1972, Fig. 24) and Briggs and Johnson (1979) have frequently found that the transition from the base of the flower to the anthopodium is externally very indistinct. Therefore, Schmid (1972) regards the axis distal to the prophylls as the basal part of the flower which is also anatomically indistinguishable from the primary axis (a_1 axis, Briggs & Johnson; pedicel, Schmid), except where the vascular traces diverge to the prophylls. Contrary to this, Briggs and Johnson (1979) regard the anthopodium as an internode of the axis below the flower. The validity of distinguishing the ultimate and penultimate flower-bearing axes requires further evaluation. The applicability of such a distinction in *Prostanthera* is not known at this stage. However, it is of interest to note that Tölken found a developmental differentiation between the two 'internodes' in *Crassula* (Toelken [Tölken] 1981). The anthopodium ('pedicel', Toelken 1982) of *Crassula pedicellosa* elongates as the fruit matures, but the a_1 axis ('peduncle', Toelken 1982) does not elongate. In section *Klanderia* it appears to be the a_1 axis (if any) which elongates as the fruit matures, not the anthopodium. In the 'Systematic Treatment' pedicel is regarded as the a_1 axis plus the anthopodium.

Two ways of interpreting the inflorescence structure of *Prostanthera* are discussed below.

One interpretation of the inflorescence of the species in section *Klanderia* is presented in figure 2. Here the uniflorescences (Briggs & Johnson 1979) [unit inflorescences, Johnson & Briggs 1975, Johnson 1976; \approx partial inflorescences, partial florescences, Troll 1964 & 1969, Weberling 1965, 1981, 1982] are regarded as monadic and the resulting conflorescence [= synflorescence, Troll 1964 & 1969] is racemiform on leafy branches (Fig. 2).

In section *Prostanthera* similar frondose racemiform conflorescences (with monadic uniflorescences) are found in *P. caerulea*, *P. cuneata*, *P. eckersleyana*, *P. spinosa* and *P. teretifolia*. *P. rotundifolia* and *P. stricta* (both sect. *Prostanthera*) have a bracteose blastotelic racemiform conflorescence (with monadic uniflorescences) on anauxotelic R_z axes (Fig. 3a), since the axis is terminated by an aborted vegetative bud. In *P. lasianthos* (Figs 3b & 4) and *P. ovalifolia* the racemiform conflorescences are arranged into a superconflorescence (*sensu* Briggs & Johnson 1979).

Troll (1964) and Weberling (1965, 1981) concluded that all of the labiate genera which they had studied, have polytelic synflorescences with "cymose 'partial inflorescences'" (Weberling 1965) [= cymose uniflorescences, Briggs & Johnson 1979]. For examples of cymose inflorescences of several labiates refer Troll (1964, Figs 62-68). In *Prostanthera* the monadic uniflorescences can be regarded as derived from the cymose condition by reduction because the primary (penultimate) axis (a_1 axis, Briggs & Johnson 1979) is uninodate with a pair of prophylls [Vorblätter, Troll 1964, 1969] occurring at this distal node (Fig. 2). Furthermore, the ultimate 'internode' [anthopodium, Briggs & Johnson

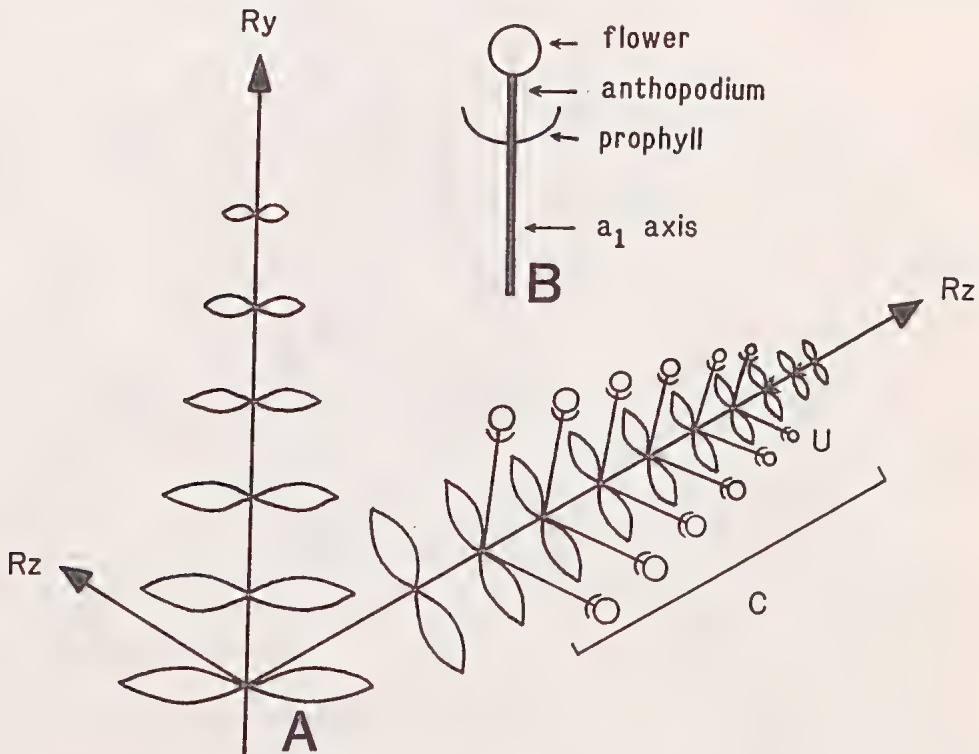


Fig. 2. Diagrams of a typical flowering branch of *Prostanthera* sect. *Klanderia*. A. general diagram; B. detail of uniflorescence, C = conflorescence; Ry = the branch from which the R_z axis arises; R_z = the branch from which the a_1 axis arises; U = uniflorescence.

1979] is terminated by a flower (Fig. 2). Frondose racemiform conflorescences typical of those found in section *Klanderia* are also found in *Westringia* (except *W. cephalantha* which has a bracteose conflorescence similar to *P. rotundifolia*). Other examples of labiates with monadic uniflorescences are *Salvia patens* (Troll 1964, Fig. 7311) and *Teucrium fruticans*.

This interpretation assumes that the labiates have a basically cymose inflorescence structure. It then follows that the single flowers have to be interpreted as uniflorescences which are aggregated into conflorescences.

A second interpretation is that the basic inflorescence should be regarded as a botryum (Figs 2 & 3a), with elaboration to form a dibotryum (Fig. 3b) or pleiobotryum [actually a tribotryum] (Fig. 4). From this it follows that the presumed 'cymose' condition found in many herbaceous labiates (e.g. *Salvia*) has resulted from modifications of the basic botryine condition.

Of the two interpretations I prefer the former. However the former one does not support the presumed phylogeny of the Labiatae subfamilies as proposed by Hillson (1959). He proposed that the Ajugoideae and Prostantheroideae are primitive relative to the other subfamilies, with the Stachydoideae as the most advanced. Since the former interpretation regards the Prostantheroideae inflorescence as derived, this subfamily is more advanced, at least on this character, than those groups which primarily have a



Fig. 3. Diagrams of typical inflorescences of *Prostanthera* sect. *Prostanthera*. a. Flowering branch of *P. rotundifolia* (Live material, Royal Botanic Gardens, Melbourne); b. Flowering branch of *P. lasianthos* (Ashby 4454, AD).

cymose condition. The latter interpretation regards the botryine condition as primitive and the 'cymose' condition as advanced. From this one can more readily support Hillson's (1959) opinion that the Prostantheroideae is one of the more primitive subfamilies.

Whether inflorescence structure reflects phylogenetic relationship is not clear without further detailed studies. Hillson (1959) concluded that other macromorphological features were not reliable indicators of phylogeny within the Labiate. Likewise, inflorescence structure may prove unsuitable.



Fig. 4. Diagram of inflorescence of *Prostanthera lasianthos*. (Ashby 5304, AD).

Prophylls ('bracteoles')

In sect. *Klanderia* the prophylls usually occur near or at the base of the calyx (hence, anthopodium reduced). The anthopodium is relatively long in *P. patens* and *P. ringens*, and is of some taxonomic value for distinguishing them from the remaining species of this section. The prophylls are soon deciduous in *P. patens*. They are usually narrow, more or less ovate to obovate in most species. Those of *P. patens* are narrower than for the other taxa.

The prophylls are usually opposite, but in *P. chlorantha* they are occasionally displaced vertically relative to each other, such that they appear to be alternate.

Calyx

The calyx varies from 4 to 15 mm long. *P. calycina*, *P. chlorantha*, *P. monticola*, and *P. walteri* have calyces which are at least 8 mm long. The other species usually have smaller calyces. The calyx is 2-lobed, with the more or less triangular lobes being approximately equal in length (Fig. 53).

Since the calyx frequently enlarges as the fruit matures, the description of the calyx, including all measurements, is based on flowering material. In fruiting material the calyx lobes remain more or less porrect (Fig. 53) unlike those in section *Prostanthera*, where the abaxial lobes incurves to cover the fruit (Fig. 52).

The calyx varies from green to maroon. Certain species appear to have only one colour (e.g. *P. florifera* has only maroon calyces), whereas other taxa (e.g. *P. serpyllifolia* ssp. *microphylla*) have populations which show the full colour range. The taxonomic significance of the colour variation is not known, but is thought to be of little importance.

Corolla

The corolla tube is slightly incurved and varies from 9 to 17 mm long. In cross-section it is more or less elliptic, frequently elliptic-ovate. The throat and mouth are slightly expanded so that the maximum width at the mouth (along shortest axis) is approximately 5 mm. [The shortest axis of the mouth is more or less equivalent to the distance between the bases of the two lateral lobes.]

The corolla is normally described as being bilabiate (2-lipped) (e.g. Bentham 1870; also refer recent flora accounts). However, the position of the two lateral lobes is such that it is frequently difficult to decide (using macromorphological features) to which lip they belong (e.g. cf. Figs 53C, 70B & 73C). To avoid possible confusion, the corolla is described as being 5-lobed; comprising two adaxial, two lateral, and one abaxial. The two adaxial lobes are more or less completely fused and are referred to, collectively, as the adaxial median lobe-pair (Fig. 53, also refer species descriptions).

The anthers, style and stigma tend to lie next to the adaxial part of the inner surface of the corolla tube. Therefore, the lobes which are an extension of this adaxial surface are the adaxial median lobe-pair. Since the pedicel (a₁ axis + anthopodium) frequently twists through at least ninety degrees, the position of the anthers, style and stigma can be used to avoid orientation problems when attempting to locate the adaxial lobe-pair. This terminology also avoids the possible confusion arising from the application of the terms upper and lower lips.

All lobes (except the adaxial lobe-pair, which is more or less porrect) become more recurved or more strongly reflexed once the anthers have fully dehisced.

The species of section *Klanderia* have corollas which are usually red, often green, and occasionally yellow. Many species, e.g. *P. aspalathoides*, show the full colour range, whereas others, e.g. *P. chlorantha*, *P. ringens*, *P. monticola* and *P. walteri* have more or

less green corollas only. It was found that when the corolla is placed in 100% ethyl alcohol, all colour forms turned red (sometimes very faintly). In contrast, the corollas of the species (23 species tested) of section *Prostanthera* almost invariably turned blue when placed in 100% ethyl alcohol, irrespective of original colour. The only exception was that species with white corollas (of sect. *Prostanthera*) became translucent to transparent. Therefore, flowers of species from section *Klanderia* have red corolla pigments which may be masked by other pigments. The corollas of species in section *Prostanthera* usually contain blue pigments with colour variation being the result of masking by additional pigments or by the possible lack of pigmentation.

The inner surface of the corolla (in sect. *Klanderia*) is usually paler than the outer surface. Frequently, the inner surface has a yellow or cream-coloured tinge (e.g. in *P. florifera*, *P. aspalathoides*). Dark, more or less maroon dots or streaks are frequently present on the distal part of the inner surface of the tube, the mouth and the abaxial median lobe.

Androecium

The flowers are protandrous (typical of most Labiatae, van der Pijl 1972), with 4 epipetalous stamens located between the abaxial and lateral lobes, and between the adaxial lobe-pair and the lateral lobes. They are inserted approximately 8 to 10 mm above the base of the corolla. The stamens are didynamous, with the two abaxial ('lower') ones longer than the two adaxial ('upper') ones.

The filaments are more or less ligulate and 5 to 8 mm long. They are basally curved towards the adaxial surface of the corolla and then extended forward, lying next to the inner adaxial surface of the corolla. The filaments are glabrous, but triangular glandular trichomes are frequently present.

The basifixed anthers are tetrasporangiate and bilocular (*sensu* Green 1980). The basal lobes of the anthers are obtuse or shortly acuminate. Triangular trichomes are frequently present on these lobes. In *P. florifera*, *P. grylloana*, *P. laricoides*, *P. patens* and *P. serpyllifolia* ssp. *microphylla*, the connective is extended to form a short appendage. In *P. aspalathoides* and *P. chlorantha*, the appendage is usually minute (mostly less than 0.3 mm long) and so, frequently appears absent. The appendage usually has a few triangular trichomes, particularly at or near the apex. The anthers are mostly obtuse to slightly emarginate apically. Dehiscence is introrse by longitudinal slits. Further details on how dehiscence is actually affected is discussed in the chapter on Pollination.

The anthers are held within the corolla, just short of the apex of the adaxial lobe-pair, and in effect are not exerted, or if so then only partially. The two abaxial anthers are distal to the adaxial pair (Fig. 53). Laterally, one abaxial and one adaxial anther are juxtaposed (Fig. 53B). The two abaxial anthers are positioned such that the ventral surfaces (dehiscence zone) of each are in contact (Figs 53 & 56F). The adaxial pair is similarly arranged. The stomium of each anther remains in contact with its opposite equivalent until dehiscence is completed. The distal abaxial pair matures first and usually completes dehiscence before the adaxial pair. Once dehiscence is completed the stamens separate and relocate (separately) next to the inner surface of the abaxial parts of the corolla tube. This is illustrated in figure 52A-C, for section *Prostanthera*. At this stage, the anthers are often exerted between the lateral and abaxial corolla lobes.

Disc and Gynoecium

The more or less cylindrical disc is usually 0.5 to 1 mm long. The 2-carpellate gynoecium, which is distal to the disc, is superior, glabrous, and 20 to 30 mm long. The 2 locules of the ovary are further divided by a false septum, so that the ovary appears to be 4-loculate (Briquet 1895; Cronquist 1968, 1981; Sharma & Singh 1982).

The ovary is 4-lobed and, although the style is frequently regarded as gynobasic (e.g. Beadle *et al.* 1976; Haegi 1981; for further references refer Carrick 1977, p. 119), it is terminal (Junell 1934; Hutchinson 1969; Hickey & King 1981; Cronquist 1981). This arrangement is found in the Prostantheroideae and in *Ajuga* (Ajugoideae) (following system of Briquet 1895). All other subfamilies of the Labiatae are usually regarded as having the typical gynobasic style (refer Briquet 1895; Junell 1934; Weberling 1981). However, Sharma & Singh (1982) have shown that although the style appears to be gynobasic in the Labiatae, it is the rapid growth of the four ovary lobes which result in the style becoming deeply sunken in between these lobes. The distal lobing of the ovary is often obscure, especially when the ovules abort. Although the placentae appear axile, Sharma & Singh (1982) have shown that the Labiatae have a 'placentation which is neither true axile nor true parietal, but [is] an intermediate condition between the two'. The septum development is typical of that found in flowers with axile placentation, except that the two placental ridges arise from the inner lateral walls of the ovary (at the fused margin of the two carpels), which is typical of parietal placentation. The ovules are anatropous, laterally to sub-basally attached on their ventral surface, two per carpel (appearing solitary because of false-septum), unitegmic and tenuinucellate (which is characteristic of the Labiatae, refer Corner 1976; Sharma & Singh 1982). The stigma is shortly bifid distally.

The various features of the gynoecium appear to be of no taxonomic importance since they are relatively invariable throughout section *Klanderia*.

Fruit and Seeds

The schizocarpic fruit is heteromericarpous (Roth 1977), comprising 4 (1-seeded) mericarps [nutlets] (Figs 64E, 71E, 75E). Winkler (1939, 1940) regards the fruits of the Labiatae as foraminose (perforated by large hole) capsules since the mericarp ('Klausen') correspond to parts of the capsule wall which separates from the remaining carpel parts by a ring-shaped cleft. This type of separation involves tissue of the median part of the capsule—one of Stopp's (1950a, 1950b) three types of foraminose capsule types. As the seeds develop, the distal lobes of the fruit (formerly those of the ovary) enlarge. The seeds are enclosed in pericarp and the seed coat is reduced to the outer integument. As pointed out by Corner (1976), the seed-coat has little structure and so is 'almost negligible'. The endosperm is cellular and oily.

A comprehensive anatomical study of the fruits of the Labiatae was carried out by Wagner (1914; as summarized by Roth 1977). He found that the structural features of the pericarp were of taxonomic use in distinguishing certain genera of the Labiatae. Wojciechowska (1958, 1961a, 1961b, 1966) used morphological and anatomical features, particularly of the sclerenchymatous layer of the pericarp, to distinguish between the fruits of a number of European Labiatae genera. Within section *Klanderia*, macromorphological features of the fruits and seeds appear to be of little taxonomic value because they are relatively invariable.

Pollination and floral biology

Introduction

Proctor & Yeo (1973) and, in particular, Faegri & van der Pijl (1979) provide brief reviews of the literature which discusses pollination in the Labiatae. The various concepts (e.g. pollination syndromes and blossom types) are mostly based on northern hemisphere species. Neither book mentions *Prostanthera* or the other genera of the Prostantheroideae. The only publication on pollination in the Prostantheroideae was by Keighery (in Armstrong *et al.* 1982) (refer p. 222). Since very little information has been published on

the breeding systems, pollination mechanisms and pollinators of *Prostanthera*, our understanding is incomplete. The extent of our knowledge, which is mostly very superficial, is summarized in this chapter.

Field observations

I have observed the Crescent Honeyeater (*Phylidonyris pyrrhoptera*) visiting flowers of *P. walteri* (sect. *Klanderia*) and unidentified honeyeaters visiting *P. florifera* and *P. monticola* (both sect. *Klanderia*). Keighery (1980) recorded three bird pollinated *Prostanthera* species from the South West Botanical Province (Beard 1980) of Western Australia. However, the method used for determining actual pollination from mere visitation is not given. He (Keighery, *in litt.*) has recorded White-fronted Honeyeaters (*Phylidonyris albifrons*), Brown Honeyeaters (*Lichmera indistincta*) and White-eared Honeyeaters (*Lichenostomus leucotis*) visiting *P. aspalathoides* [the locality suggests that this species is *P. incurvata*], *P. grylloana* and *P. microphylla* (= *P. serpyllifolia* ssp. *microphylla*); Singing Honeyeaters (*Lichenostomus virescens*) visiting the first two *Prostanthera* species; Purple-gaped Honeyeaters (*Lichenostomus cratitius*) visiting *P. grylloana*; and Western Spinebills (*Acanthorhynchus superciliosus*), Tawny-crowned Honeyeaters (*Phylidonyris melanops*) and Red Wattle-birds (*Anthochaera carunculata*) visiting *P. microphylla* (= *P. serpyllifolia* ssp. *microphylla*). The only other published report was by Ford *et al.* (1979), who recorded bird pollination (at least in one species) in the Labiatae. Ford (*in litt.*) verified that Black-eared Miners (*Manorina melanotis*), Purple-gaped Honeyeaters and White-fronted Honeyeaters have been observed feeding on the nectar of the flowers of *P. aspalathoides* (sect. *Klanderia*). He also collected probable *Prostanthera* pollen from two Purple-gaped Honeyeaters, one Singing Honeyeater and one Tawny-crowned Honeyeater from Monarto, South Australia (Ford, *in litt.*). Watts (*in litt.*) observed Fuscous Honeyeaters (*Lichenostomus fuscus*) and less frequently, Red Wattle-birds, Tawny-crowned Honeyeaters and Yellow-tufted Honeyeaters (*Lichenostomus melanops*) feeding on the nectar of *P. aspalathoides* in the Inglewood area, Victoria.

I have observed bees visiting flowers of *P. behriana*, *P. lasianthos*, *P. ovalifolia*, *P. rotundifolia* and *P. striatiflora* (all sect. *Prostanthera*). Keighery (1980) recorded eleven insect pollinated *Prostanthera* species, two of which, *P. eckersleyana* and *P. wilkeana* (both sect. *Prostanthera*), were visited by bees and wasps (Keighery, *in litt.*).

The structural floral differences between the flowers of the two sections (Figs 52 & 53) strongly reflect the presumed pollen vectors. Although the pollen vectors appear to be different for each section, the actual mechanism of pollination is thought to be probably very similar throughout the genus.

Pollination mechanism in section *Klanderia*

Birds feed on the nectar produced by the disc, at the base of the gynoeceum. As the beak and part of the forehead of the bird enter the flower, the staminal filaments are displaced laterally. This also causes the anthers to be laterally displaced, thus exposing the pollen within the locules. As the bird's beak and forehead brush past the exposed pollen, which is slightly sticky, the pollen is transferred to the bird's beak. When the bird withdraws from the flower the anthers return to their initial position with the dehiscence zones in contact. The lateral displacement of the anthers (hence filaments) is achieved in two ways. Firstly, the corolla mouth is usually narrowest between the lateral lobes. Therefore, the pollen vector comes in contact with the lateral parts of the corolla. This lateral distortion of the corolla actually shortens the distance between the abaxial and adaxial lobes. This shortening brings the anthers into closer contact with the pollen vector. Secondly, this lateral displacement of the anthers is also achieved by the presence of an anther appendage(s) (for examples, refer p. 229). The appendage is more or less

orthogonal to the shortest axis of the corolla mouth. This ensures that the pollen vector will laterally displace these appendages (and hence, the anthers) while probing the flower for nectar. Triangular trichomes are frequently present on the more distal parts of the filaments and on the basal lobes of the anthers. These trichomes probably improve the contact between the stamens and the pollen vector. It is envisaged that this may assist in the dislodgement of the pollen from the locules and so, may result in improved pollen transfer. A similar mechanism was found in *Dicerandra* (Labiatae) from the southern United States of America by Huck (1981). She suggested that the anther appendages (spurs) in this genus (particularly those of *D. odoratissima* which show many similarities to those of *Prostanthera*) ensure an efficient transfer of pollen.

Pollination mechanism in section *Prostanthera*

The main floral structural difference between this section and sect. *Klanderia* is that the flowers of sect. *Prostanthera* have the shortest axis of the corolla mouth between the abaxial and adaxial lobes, not between the lateral lobes. There is still some lateral distortion of the corolla as the pollen vector enters the flower (particularly with Honey bees). However, further comment at this stage would be premature, since more detailed observations are necessary.

Floral biology and ornithophily in section *Klanderia*

Faegri & van der Pijl (1979) have summarized the typical ornithophilous syndrome (also refer Proctor & Yeo 1973). In general, the flowers of the species in section *Klanderia* have characteristics comparable to those of typical ornithophilous species. These characteristics include: a relatively strong more or less tubular corolla (Fig. 53); the lack of floral scent; abundant nectar; the displacement of anthers and stigma from the nectary; the corolla's lacking a landing stage; and the basic colour of the corolla's being red.

According to Faegri & van der Pijl's (1979) classification system of blossom types (pollination units), *Prostanthera* (in fact, most of the Labiatae) have a gullet-shaped blossom (Faegri & van der Pijl 1979, p. 89—I.2.D.,—Fig. 49). Keighery (in Armstrong *et al.* 1982) lists 4 genera of the Prostantheroideae which he regards as having gullet-shaped blossom. In this type of corolla, the androecium, style and stigma (of the gynoecium) are 'restricted to the upper [adaxial] side of the "pollination unit" and pollen is deposited nototribically, on the vector's head' (Armstrong 1979). Although the flowers normally hang down, except in more or less prostrate forms where the corolla mouth is directed upwards (e.g. *P. serpyllifolia* at Innes National Park on exposed limestone cliffs, *P. walteri* on exposed sites), the birds have no difficulty perching (often upside down) on the distal branches while probing the flowers for nectar. The slightly sticky pollen found in flowers of this section, which adheres to the bird's beak, is typical of ornithophilous flowers (Ford *et al.* 1979).

Those flowers which have greenish corollas frequently have calyces which have, at least distally, a red-purple tinge. Therefore, this red-purple tinge may compensate for any effects caused by the masking of the red corolla pigments by contrasting the flower against the green foliage. At least to the human eye, a calyx with a purple tinge is almost as obvious against the green background of the foliage as is a red corolla. This contrast between red (including purple) and green is quite effective and is common in a number of groups. A similar contrast was noted by Conn (1980), with respect to seed dispersal in *Geniostoma* (Loganiaceae).

Raven (1972) pointed out that red and orange colours are not conspicuous to insects, except possibly butterflies. Therefore, flowers of these colours would blend with the green foliage. Furthermore, even if abundant carotenoids are present (as in many orange flowers), their ultraviolet reflectivity (which is conspicuous to insects) is partially, if not

totally masked by the red anthocyanins of the same flowers (Raven 1972). However, red and orange are at least as conspicuous to birds as they are to humans (Knoll 1956; Faegri & van der Pijl 1979), if not more so (Gottsberger 1971).

Several studies (e.g. Grant & Grant 1968) have shown that birds do not necessarily appear to have an intrinsic preference for red, but it is thought that they learn to associate this flower colour with the high caloric rewards of the nectar (Raven 1972). Typical of ornithophilous flowers, those of section *Klanderia* are scentless. Since insects are attracted by odour (Faegri & van der Pijl 1979), they are not aware of the nectar rewards provided by these scentless flowers.

Ford *et al.* (1979) discuss the possible advantages of ornithophily with respect to pollination efficiency, and other related aspects. For instance, they point out that birds can carry more pollen than insects, and so, can pollinate more flowers. They suggest that the production of fewer flowers may be a response which compensates for the increased energy required to produce larger, stronger flowers with greater quantities of nectar. The increased nectar supply being required to adequately provide for the higher energy requirements of birds (Ford & Paton 1976). Ford (*in litt.*) obtained an average nectar content/flower for *P. aspalathoides* (based on 6 flowers) of 8.7 μ l with sugar concentrations of 28% by weight of sucrose equivalents. This relatively large quantity of nectar with a corresponding high caloric content is typical of ornithophilous plants. For example, Pyke (1980) obtained an average sugar concentration for plants visited by honeyeaters of 20.4% by weight of sucrose equivalents, and Ford (in Pyke 1980) obtained a value of 21.7%. Paton & Ford (1977) and Pyke (1980) have shown that plants frequented by honeyeaters have nectar with relatively high mean caloric content (overall average 8.4 calories per flower, Pyke 1980). The racemiform inflorescence (of sect. *Klanderia*) may be an adaptation to ornithophily. However, some species of section *Prostanthera* (e.g. *P. spinosa*) have a similarly reduced inflorescence. Ford *et al.* (1979) also suggest that birds visit more flowers (of a population) more frequently than do insects. Observations of birds visiting *P. walteri* and *P. monticola* (sect. *Klanderia*), compared with bees visiting *P. striatiflora* (sect. *Prostanthera*) support this. However, bees appeared to visit plants of *P. lasianthos* (sect. *Prostanthera*) (at Mt Ellery, Victoria) as frequently as the birds for *P. walteri* (also Mt Ellery). Unfortunately, no quantitative data are available, so a comparison is not possible. Although the relative efficiency of birds and insects as pollinators can be measured in terms of frequency of visits to flowers, frequency of visits to separate plants, amount of pollen carried, and so on, a consideration of the relative production of viable seeds would be necessary so that the actual effectiveness of each could be evaluated.

Breeding system in section *Klanderia*

In the absence of a more substantial body of information on the subject, a very preliminary and speculative summary is offered. Since the flowers are protandrous, with the stigma only receptive once the anthers have dehisced, species of section *Klanderia* appear to be essentially outbreeders. This is further ensured because the immature stigma lies between the apices of the anthers and the adaxial surface of the corolla ('above' the anthers). Furthermore, stylar elongation exserts the mature stigma beyond the adaxial corolla lobe-pair without making contact with the staminal dehiscence zones. Hence, the flowers are dichogamous and herkogamous. Therefore, there appears to be no self-pollination mechanism within individual flowers. It seems likely that these ornithophilous species (of sect. *Klanderia*) are dependent for fertilization on visits from the pollen vector, since they lack self-pollination mechanisms within individual flowers. Whether or not flowers which have not been visited by pollen vectors are capable of producing viable seeds is not known. However, the developmental sequence of the racemiform inflorescence is such that flowers at all stages may be present on any individual plant. Therefore,

geitonogamy is potentially possible. In *P. walteri*, birds were observed to visit open flowers, irrespective of maturity. Furthermore, the birds visited several flowers on the same bush before visiting flowers of another bush. Whether or not self-fertilization occurs depends on the level of self-compatibility, although protandry would give a slight advantage to out-breeding.

Seed dispersal and seedling establishment

Labiatae fruits are synaptospermous (all mericarps released as a whole) (Roth 1977). In section *Klanderia* the calyx and the pedicel (a_1 axis + anthopodium) remain attached to the fruit and so fall with the mericarps. Fruits which remain on the plants, after the majority have fallen, usually contain a significantly high number of aborted seeds.

The actual seed dispersal mechanism is not known. In the Dandenong Ranges (Victoria) I have observed bird dispersal of *P. lasianthos* seeds which resulted in successful seedling establishment. However, it seems likely that the mericarps usually fall directly to the ground with very little lateral displacement caused by air-currents.

Seedlings appear to be rare (in sect. *Klanderia*) and usually occur near the base of the parent plant. In *P. behriana* (sect. *Prostanthera*) (at Monarto South, South Australia), seedlings were only found amongst the dead branches (which lay on the ground). It is assumed that these seedlings were not grazed because they were protected by the tangle of branches. However, grazing by wallabies has been observed for *P. spinosa* (sect. *Prostanthera*) on Kangaroo Island, South Australia (refer Conn 1081-1084). The soft juvenile shoots of this species are heavily grazed, but the older shoots are protected by the hardened spines. Cunningham *et al.* (1982) note that *P. aspalathoides* and *P. leichhardtii* (= *P. ringens*) are not grazed by stock, but *P. microphylla* (= *P. serpyllifolia* ssp. *microphylla*) is only grazed when other feed is very limited. *P. florifera* appears to be grazed, probably by kangaroos and livestock. In general, more observations are necessary before the extent of grazing and its possible role, if any, in seed dispersal can be evaluated.

Propagation of section *Klanderia*

Although several of the species of section *Prostanthera* are commonly cultivated in public and private gardens, those of section *Klanderia* are only sometimes found in public gardens, rarely in private gardens. There appear to be no cultivars involving species of this section. The techniques used to cultivate *Prostanthera* species are discussed in Althofer (1978), Anon. (1971) and Anon. (1977).

Numerical Analysis

Introduction

In numerical taxonomy, any biometric analysis which attempts to organize individuals into groups is regarded as classificatory. There are many aspects specific to numerical classification which are discussed in Williams (1971, 1976). These are not discussed here because they do not represent further differences from non-numeric concepts of classification. Lance & Williams (1967) also include the simplification of the data by ordination as a type of classification. However, ordination does not necessarily lead to the recognition of groups within the sample being tested. The principal difference between classification and ordination is that the former is concerned with the organization of individuals into groups, whereas the latter is concerned with the relationship between the individuals.

One important feature of a non-numerical classification is that the discrete groups are arranged relative to each other after being assigned to a certain rank. In numerical phenetics, hierarchical classification (Williams 1971) presents a similar arrangement which can be readily expressed in two dimensions in the form of a phenogram. However, the individuals are arranged relative to a set of ultrametric distances which define the phenogram. These ultrametric distances are the transformed set of pair-wise dissimilarities (Sneath & Sokal 1973). McNeil (1978) clearly summarized the differences between non-numeric classification and phenograms as (i) classifications are rank-defined, whereas (ii) phenograms are distance-defined. The distance value of a phenogram is the 'actual fusion-level derived from the distance or dissimilarity being used' (McNeil 1978).

McNeil (1978) added to Farris' (1977) definition of classification that a 'phenetic classification should also have a predictive element'. This is similar to Dagnelie's (1966) identification concept for numerical classification. Therefore, McNeil's definition is preferred since it is comparable to that used by most non-numerical taxonomists.

Selection of morphological characters

An estimate of resemblance between organisms is based on a consideration of as many features as possible of the individuals concerned. In classical taxonomy these features are usually known as taxonomic characters, whereas the literature of numerical taxonomy contains a number of terms (e.g. character, attribute, variable) which have been variously defined and hence, applied differently by different authors. The term character has been most commonly used as 'a property which differentiates a taxon of any rank from at least part of the taxa of the same rank which are all subordinated to the same taxon at the next higher level' (Leenhouts 1968). A similar definition was used by Mayr (1969). In this sense, characters are defined as the *differences between taxa*, but as pointed out by Sneath & Sokal (1973), 'the taxa cannot be recognized without the characters themselves being first known'. Therefore, this definition is inappropriate.

In this study, a definition similar to that of Cain and Harrison (1958) is used. That is, a *character* is regarded as 'any attribute (or descriptive phrase) referring to form, structure or behaviour which the taxonomist separates from the whole organism for a particular purpose such as comparison or interpretation' (Davis & Heywood 1963). Therefore, character is here used in a similar sense to that of attribute, as used by Clifford & Stephenson (1975), and Williams (in Williams 1976). Hence, character states are the expression or nature of the character concerned and are not used in the sense of Jardine (1969). Sokal and Sneath (1963) proposed the term *unit character*. Although the concept is possibly theoretically sound, it seems likely that division of characters into units will frequently be difficult. Therefore, as a working definition, the more general definition of Davis and Heywood is preferred.

Pre-numerical analysis

Prostanthera section *Klanderia* was initially studied using classical (non-numerical) taxonomic procedures (refer p. 211 for details of general procedure followed). The amount of herbarium material available for study was far too much to be taxonomically analysed as one unit. Hence, the material was initially sorted into broad geographical units. These units mostly corresponded with State boundaries, although more natural geographical units such as mountains, mountain ranges and islands were also used. Each unit was of a more manageable size than the unsorted material since (within each unit) there are fewer taxa to be dealt with or, in the case of widespread species, less variation than expressed over its entire area of distribution. Within each unit duplicates and population collections were grouped together so that a more reliable impression of the morphological variation within either individuals or populations could be achieved. Finally, entities (specimens or

populations) which showed a strong mutual gross morphological resemblance were grouped together. Entities which appeared intermediate between any two groups were kept separate and were carefully compared with each group at a later stage. Many of these intermediate entities occurred near State boundaries of what proved to be more widespread species (e.g. *P. aspalathoides*). Several of the groups formed as a result of the above sorting proved to be morphologically homogeneous within each group, as well as morphologically distinct from the other groups. These groups are recognized as distinct species (viz. *P. chlorantha*, *P. florifera*, *P. grylloana*, *P. monticola*, *P. porcata*, *P. ringens* and *P. walteri*).

The choice of characters and the final character set used are discussed below and in Table 1. With the exception of those characters involving density of hairs and glands, all characters listed in Table 1 were used in this non-numerical taxonomic analysis and so form the basis of the botanical descriptions.

The remaining (less homogeneous) groups, including *P. florifera* (refer Fig. 5 for locality of groups) were analysed in more detail by numerical techniques (refer pp. 231-245). These largely arbitrary groups were used to evaluate the character set (pp. 227-231) and to evaluate the suitability of these groups as classificatory units (pp. 231-237). The modified classification which arose out of these analyses (pp. 235, 236) resulted in three species complexes being recognized (viz. *P. aspalathoides*, *P. calycina*-*P. microphylla*-*P. serpyllifolia*, and *P. laricoides*). The morphological structure of each of these was then analysed in further detail (pp. 237-245).

Method used to select morphological characters

During the initial classical taxonomic analysis of sect. *Klanderia* a general overview of this section was obtained and various taxonomic problems were located. In addition to this, characters were evaluated for their taxonomic usefulness based on knowledge gained from my preliminary taxonomic investigation of this section.

The selection of characters was based on a number of criteria. The only characters used were those which could be consistently measured so as to represent unambiguously the relevant feature. It was found that corollas could not be measured so as to represent consistently and accurately the true shape. A number of factors determine the ultimate corolla shape. Maturity and position of the corolla, relative to the foliage and branches, are two of the most important factors which may lead to changes of the corolla shape. The extent of recurvature of the corolla lobes is another factor which determines the overall shape of the corolla and it was not possible to measure accurately the extent of this recurvature. Furthermore, this feature appears to be correlated with anthesis and fertilization. The problems that I have encountered in trying to use the various aspects of corolla shape as taxonomic characters, commonly occur in many groups which have bilabiate corollas. Ideally, fresh material which has been grown under controlled conditions is necessary. Although many collections were specifically made for this study (alcohol preserved material being available for most of these), intensive collecting would have been necessary to ensure that suitably preserved corollas would be available for a much larger data set. Unfortunately, this was not feasible during this study.

Since I was in part relying on herbarium material, of which some was not collected specifically for this study, I chose characters which were present on most of the collections. Finally, I avoided characters which appeared to be invariable (e.g. those of fruits, hence mericarps; those of seeds; and magnitude measurements of corolla tube, mouth and lobes). The invariability of such characters was determined by measuring selected specimens from different taxa.

The level of correspondence between the various character states and the different taxa was not known. For example, *P. aspalathoides*, *P. microphylla* and *P. serpyllifolia* are

usually differentiated on the basis of the size and shape of the leaves, and the presence or absence of an anther appendage. However, during my preliminary study it was noted that it was frequently difficult to classify certain specimens into any of these three taxa on the basis of leaf length or shape. Furthermore, specimens which appeared to belong to *P. aspalathoides* on leaf characteristics, had short anther appendages whereas other similar specimens lacked this appendage. Traditionally, *P. microphylla* (= *P. serpyllifolia* ssp. *microphylla*) is usually distinguished from *P. aspalathoides*, at least in part, by the former taxon having an anther appendage and the latter, supposedly lacking this appendage. Therefore, my preliminary study indicated that should a difference exist between these two taxa, with respect to the anther appendage, then it was more likely to be quantitative than qualitative.

The taxonomic importance of the various aspects of indumentum (glandular and eglandular) was more uncertain than most of the above characters. As mentioned before, there are differences between taxa with respect to the position of the hairs on the branches, and some taxa have glabrous branches whereas others were hairy. Similarly, differences in the shape of the hairs on the branches were of unknown importance. Therefore indumentum characters were included in the final character set so that they could be rigorously evaluated by biometrical techniques.

The raw data is not included because of its bulk, but it is available from MEL on request. The morphological characters used are listed, with brief explanations in Table 1. The density of hairs and glands were measured using a glass ocular graticule. The number of hairs or glands in one millimetre square were counted and the average of five separate density measurements were used. The other features (refer Table 1) are self-explanatory and so will not be discussed further.

Table 1. Final character set used in the various biometrical analyses

AAL	length of anther appendage (mm), if two appendages then length of longest appendage
BL	length of prophyll (mm)
BLW	length to width ratio of prophyll
INTER	position of hairs on branches—hairs absent (0), hairs on two opposite sides (1), hairs on all sides (2)
KGDO	density of glands on outer surface of calyx (number of glands/mm ²)
KHDI	density of hairs on inner surface of calyx (number of hairs/mm ²)
KHDO	density of hairs on outer surface of calyx (number of hairs/mm ²)
KL	length of calyx (mm)
KLLT	length of calyx lobes to length of calyx tube ratio
LGD	density of glands on leaf (number of glands/mm ²)
LHD	density of hairs on leaf (number of hairs/mm ²)
LKLP	position of prophyll on pedicel (anthopodium length divided by a_1 axis) (see Fig. 2B)
LL	length of lamina (mm)
LLW	ratio of lamina length to maximum width of lamina
LLWL	position of maximum width of lamina (distance maximum width of lamina from base divided by length of lamina)
LPLL	length of petiole to length of lamina ratio
PL	length of pedicel (mm) [anthopodium + a_1 axis] (see Fig. 2B)
STBB	length from base of hair to first bend of hair (mm). Hairs of branches measured
STGD	density of glands on branches (number of glands/mm ²)
STHD	density of hairs on branches (number of hairs/mm ²)
STHL	length of hairs on branches (mm)
STHW	basal width of hairs on branches (mm)
STMX	maximum distance any part of hair (of branches) is from surface of branch (mm)

Evaluation of character set

Since the characters used form the basis of the subsequent classification, these characters were critically evaluated for both their validity and their taxonomic value. The assessment of the characters included a consideration of the discriminatory 'power' (or uniqueness of the information content of each), the variability of each, and the extent of redundancy of information in the characters as a whole.

Initially, the fundamental distributional characteristics of the characters (of the individuals examined) were analysed (using subprogram CONDESCRIPTIVE, Nie *et al.* 1975) and some of the statistics are presented in Table 2. The significance of the deviation from normality of kurtosis and skewness were tested using the *t*-test (as modified by Sokal & Rohlf 1969). All characters were nonparametrically distributed. Therefore, statistical tests which assume normality were not used, except on transformed data (that is, data standardized by range; refer pp. 236 & 245).

Bivariate correlation analysis was used to evaluate the extent of the redundancy of information for each character. The nonparametric rank-order correlation coefficients of *Kendall's tau* were computed (using subprogram NONPAR CORR, Nie *et al.* 1975). *Kendall's tau* gives a measure of how similar any two characters are without making any assumptions about the distributional characteristics of the characters. The most common significance test is whether a sample correlation coefficient could have come from a population which has a correlation coefficient equal to zero (that is, $H_0: \rho = 0$). A *t*-test with $n-2$ degrees of freedom was used to test the hypothesis (refer Bailey 1959; Sokal & Rohlf 1969). Those pairs of characters with the highest correlation coefficients (those greater than 0.4 or less than -0.4, at the 0.001 significance level) are presented in Table 3. No character pairs varied significantly from zero. Therefore, all characters appear to provide a high level of 'uniqueness' with respect to their information content.

Table 2. Various statistics of the complete character set. For explanation of the character abbreviations, refer Table 1.

Character	Mean)	Range	Standard Error (Standard Deviation of Mean)	Standard Deviation (Variance)	Kurtosis	Skewness
INTER	1.77	0-2	0.02	0.50	3.49	-2.07
STHD	105.68	0-468.81	2.38	58.43	6.81	1.66
STGD	32.24	0-174.18	1.06	26.13	4.83	1.97
LPLL	0.06	0-0.52	0.003	0.07	2.44	1.16
LL	4.27	1-19	0.10	2.39	3.34	1.37
LLW	5.02	1-31.25	0.15	3.71	7.60	1.92
LLWL	0.48	0-4.33	0.01	0.30	56.17	4.95
LHD	18.22	0-486.09	1.39	34.18	88.77	7.85
LGD	42.57	1.89-230	1.13	27.76	11.76	2.75
PL	2.80	0.75-13	0.08	1.88	10.84	2.98
BL	2.56	0.5-5.25	0.03	0.63	1.57	0.23
BLW	5.26	1.6-11.67	0.06	1.40	1.49	0.51
LKLP	0.07	0-1.31	0.01	0.15	23.12	4.07
KL	7.43	3.95-13	0.06	1.37	1.19	0.87
KLLT	0.64	0.14-1.1	0.01	0.14	1.04	0.06
KHDO	15.38	0-219.28	1.13	27.82	16.41	3.38
KGDO	16.31	1.9-132.5	0.55	13.58	22.22	3.95
KHDI	10.15	0-533.89	2.02	49.61	47.14	6.42
AAL	0.36	0-2.5	0.02	0.38	2.53	1.38
STHW	0.31	0-0.11	0	0.01	3.51	0.19
STHL	0.21	0-0.53	0.01	0.09	1.77	0.55
STBB	0.09	0-0.47	0.01	0.05	9.94	1.51
STMX	0.12	0-0.74	0.01	0.06	20.87	2.25

Table 3. Correlation coefficients for selected character-pairs. For explanation of character abbreviations, refer Table 1.

Character — Pair	Kendall's Tau
INTER — KHDl	- 0.4834
LPll — LLW	- 0.5498
LL — LLW	0.6359
LL — LHD	- 0.4054
BL — BLW	0.5029
STHW — STHL	0.4945
STHL — STBB	0.4374
STBB — STMX	0.5794

The most variable characters are hair and glandular density of the branches, leaves and calyx (Table 2). The amount of variability and reliability of a character as a delimitator of taxa is usually assessed by the variance-ratio or *F*-test, which is an analysis of variance (refer Williams & Stephenson 1973; Stephenson *et al.* 1974). The *F*-test considers the ratio of the between-group variance to that of the within-group variance. However, since this test assumes that the within-group values are normally distributed, in most instances it was not used to evaluate the taxonomic usefulness of the characters for the complete data. However, the *F*-test was used in the stepwise options of subprogram DISCRIMINANT (Klecka [& Tuccy], in Nie *et al.* 1975). The selection of the characters giving the best separation of the groups was achieved by the use of WILKS and RAO stepwise methods of subprogram DISCRIMINANT (Klecka [& Tuccy], in Nie *et al.* 1975). In the above two stepwise methods, the independent characters are selected for inclusion into the Canonical variate analysis on the basis of their discriminating power. The WILKS method takes into account the differences between the centroids and the homogeneity of the groups, whereas RAO emphasises the greatest separation of the groups. For further details of these two methods refer Klecka, in Nie *et al.* 1975.

The results of both step-wise procedures are summarized in Table 4 (only the first 12 characters are presented). The discriminatory power of all characters (except LGD and BLW, which had 'F TO ENTER' values of 0.7019 and 0.7808, respectively) is high since Wilk's lambda is low. The change in Rao's *V* indicates that the change in distance between group centroids is statistically significant. All characters were retained for further analyses (unless otherwise stated) because there was no obvious 'cut-off' point. Information concerning the first three extracted canonical variate functions is given in Table 5. Changes in Wilk's lambda (associated with the chi-square significance test) indicate that the characters being used have considerable discriminatory power, at least for the first

Table 4. Statistics of the first 12 characters selected by Canonical variate analysis (significance of Wilk's Lambda and change in Rao's *V* is 0.000). Refer Table 1 for explanation of character abbreviations.

Character Step No.	entered	Wilks <i>F</i> ratio	Lambda	Change in Rao's <i>V</i>	Rao's <i>V</i>
1	KHDl	86.5099	0.24295	1816.71	0.1E+04
2	LPll	77.7913	0.06900	3303.99	0.1E+04
3	INTER	68.0464	0.02437	4775.13	0.1E+04
4	KGDO	52.6431	0.01436	5807.01	0.1E+04
5	KHDO	51.0544	0.00557	6760.21	953.1987
6	LKLP	46.1469	0.00295	7610.29	850.0809
7	KL	42.3132	0.00165	8162.18	551.8912
8	LLWL	38.0996	0.00111	8660.18	498.0020
9	AAL	34.8443	0.00076	9151.25	491.0680
10	STHL	32.1295	0.00054	9540.86	389.6039
11	KLLT	29.7643	0.00041	9896.58	355.7237
12	STMX	27.6719	0.00032	0.1E+05	235.0866

Table 5. Statistics of the first three Canonical variate functions (significance of Wilk's Lambda is 0.000).

Canonical variate function	Eigenvalue	% of variance	Canonical correlation	Wilks Lambda	Chi-squared	D.F.
1	6.81100	36.49	0.93379	0.00122	3906.0	400
2	4.21830	22.60	0.89909	0.00639	2943.6	361
3	2.44118	13.08	0.84226	0.02198	2223.7	324

Table 6. Standardized Canonical variate coefficients for function 1 of the 13 most important characters.

Character	Function 1
KHDI	-0.63857
KGDO	-0.45391
INTER	0.44090
LKLP	-0.24470
STHW	0.14436
STHL	0.13829
LHD	0.12477
LPLL	0.11991
AAL	0.11476
LLW	0.07819
KLLT	0.07706
BL	-0.05880
STHD	0.05612

three functions. The eigenvalues (a measure of the relative importance of the canonical variate function) indicate that the first three functions (in particular, function 1) are very important when considering the complete data set. The characters which contribute most to the first standardized canonical variate function are KHDI, KGDO, INTER, and LKLP (Table 6). However, all coefficients are relatively low and no single character or group of characters are obviously more important than the majority of other characters. Rather, a number of characters are collectively important discriminators in function 1. A similar trend was found in functions 2 and 3.

Principal component and principal factor analyses (using the various options of subprogram FACTOR, Kim, in Nie *et al.* 1975) were used to determine the contribution of each character to the overall variance of the character set. Those characters which contribute the least to the overall variance are the least efficient in delimiting taxa.

The PA2 method of subprogram FACTOR (Kim, in Nie *et al.* 1975) was used because it uses an iteration procedure for improving the estimates of communality. Only those factors with eigenvalues > 1 were extracted (MINEIGEN = 1), since factors with eigenvalues less than 1 account for less of the total variance than does a single character. Option VARIMAX (of subprogram FACTOR) was used to maximise the contribution of the first factor. This option rotates the axes orthogonally. As there was no prior reason to assume that there was correlation between factors, this option (VARIMAX) was used rather than option OBLIQUE (which assumes that factors are correlated).

The first three axes (factors) of principal factor analysis account for 33% of the variance. Characters KHDI, LPLL and INTER loosely cluster in the plot of factor 1 versus factor 2 (not presented here). STHL, KLLT and STMX also loosely cluster on this same plot. However in general, there was very little clustering of characters on the three factors.

After consideration of the statistics from the various analyses (as discussed above) all

characters were retained to form the final character set (Table 1). However characters STBB, STHL, STHW and STMX (all referring to features of the hairs on branches) were not used in analyses which included specimens with glabrous stems. All characters are numeric (= numeric attribute, Williams, in Williams 1976), except for INTER which is ordinal (= ordinal attribute, Williams, in Williams 1976).

Numerical analyses of specimens

A number of species, (viz. *P. chlorantha*, *P. florifera*, *P. grylloana*, *P. monticola*, *P. porcata*, *P. ringens*, and *P. walteri*) were sufficiently distinct using non-numerical procedures that further detailed biometrical analyses of these taxa were not necessary. However, *P. florifera* was included in the initial biometrical analyses so that additional clarification of the distinctness of this species from *P. aspalathoides* could be achieved. The complexes which were studied in detail included the following taxa (as circumscribed by Bentham 1870): *P. aspalathoides* s. lat. (incl. the *P. laricoides* complex of Western Australia), *P. calycina*, *P. microphylla*, and *P. serpyllifolia*. Initially the specimens (refer Conn 1982, pp. 258-264) were assigned (using non-numerical methods) to 23 groups. These groups were morphologically defined using a relatively 'narrow' concept, and they included a consideration of distribution. Therefore, the 23 groups were a reflection of apparent morphological similarity and, in most cases, approximately represented geographical regions (Fig. 5 and p. 225). This initial classification was tested using canonical variate analysis.

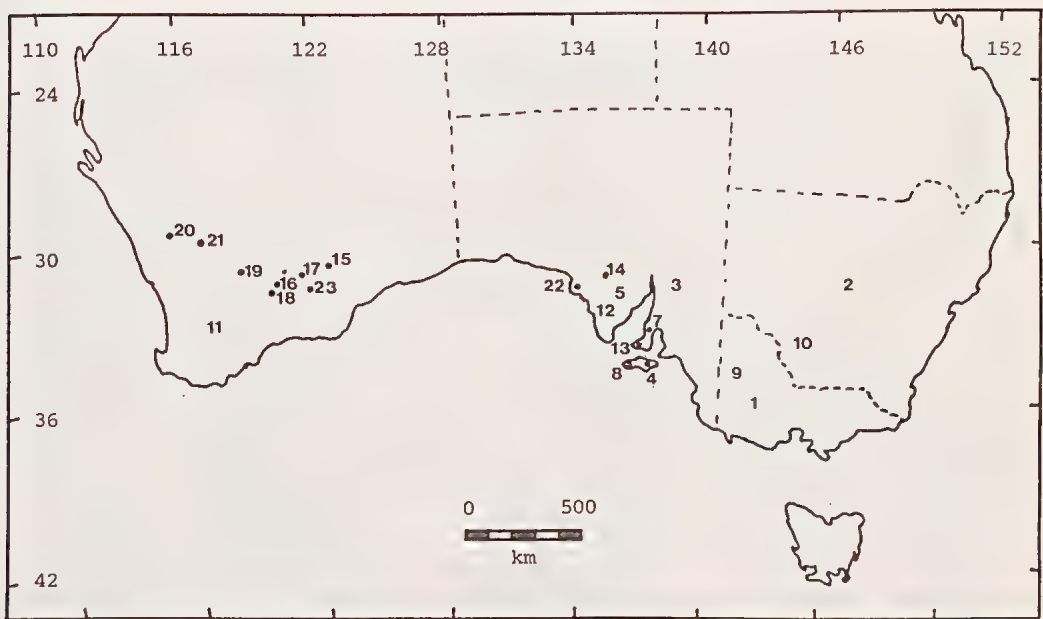


Fig. 5. Locality details of the 23 groups of the *P. aspalathoides*, *P. calycina*—*P. microphylla*—*P. serpyllifolia*, and *P. laricoides* complexes. Symbols are: *P. aspalathoides* — 1 = Victorian specimens, 2 = specimens from New South Wales, 3 = mainland South Australian specimens, 4 = Kangaroo Island specimens; '*P. microphylla*' — 5 = Eyre Peninsula specimens, 6 = Fleurieu Peninsula specimens, 7 = Yorke Peninsula specimens, 8 = Kangaroo Island specimens, 9 = Victorian specimens, 10 = specimens from New South Wales, 11 = Western Australian specimens; *P. serpyllifolia* — 12 = Eyre Peninsula specimens, 13 = Innes National Park specimens; 14 = *P. florifera*; 15 = *P. laricoides*; 16 = *P. semiteres*; 17 = *P. incurvata*; 18 & 19 = *P. semiteres*; 20 = *P. pedicellata*; 21 = *P. patens*; 22 = *P. calycina*; 23 = *P. incurvata*.

Canonical variate analysis (also known as multiple discrimination analysis) is a statistical technique which is used to test the significance of the differences between the (*a priori*) groups of the classification over all characters. It is not a pattern analysis (as used by Williams & Gillard 1971) or a classificatory technique because it arises when a classification already exists. The weighting [discriminant] coefficients computed are derived so that within-group variance is minimal and conversely, between-group variance is maximal. Sneath (1964) criticized the validity of this type of character weighting. He pointed out that characters cannot be weighted on the basis of their *within*-group constancy since it involves the *a priori* assumption of defined groups (cf. Leenhouts' definition of a character, refer p. 225. However, since it can be assumed that each of the replicate samples (of individuals or populations, refer p. 211) used in this study represent one taxon, these replicates provide a useful means by which the suitability of any classificatory technique can be checked. This technique for checking classifications has been used and recommended by several workers (e.g. Farris 1966; Sandland & Young 1979; Johnson 1982).

The DIRECT method of subprogram DISCRIMINANT (Klecka [& Tuccy], in Nie *et al.* 1975), in which all characters presented are entered concurrently into the analysis, was used to test the initial classification.

The relationship between the groups, as expressed by canonical variate functions 1 and 2 is illustrated in the resulting scattergram (Fig. 6). The most striking feature of this scattergram is the separation of the Western Australian taxa (groups E - K & M) (Fig. 6) from the South Australian-eastern States taxa (with the exception of group A [from Western Australia] which is placed with the South Australian groups).

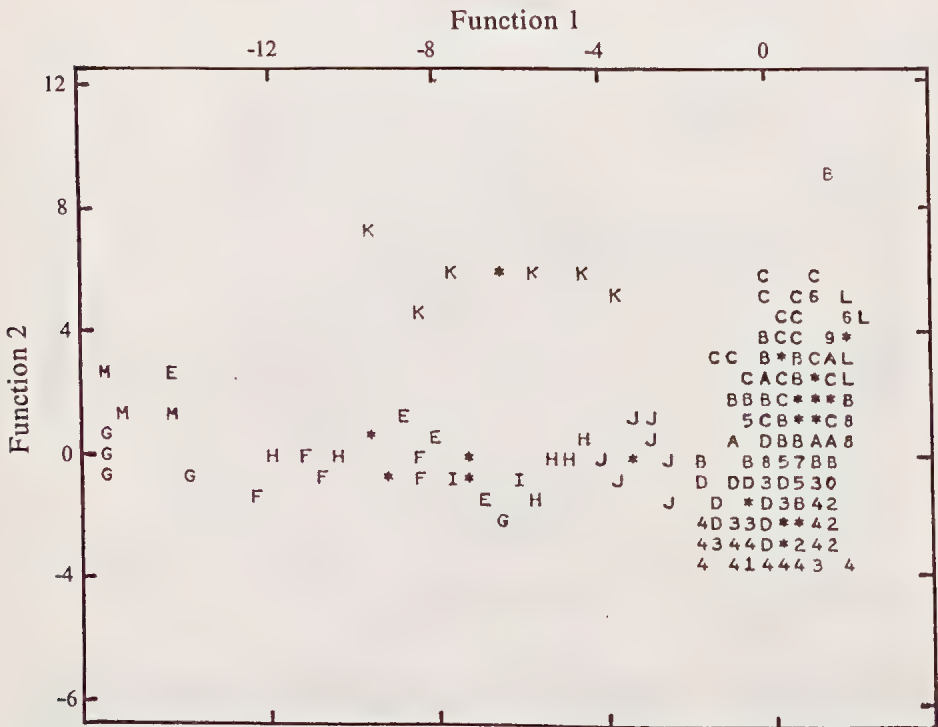


Fig. 6. Canonical variate scattergram (function 1 versus function 2) of the initial 23 groups of *P. aspalathoides*, *P. calycina*—*P. microphylla*—*P. serpyllifolia*, and *P. laricoides* complexes. For details of taxa refer Fig. 5. 1 = 1; 2 = 2; 3 = 3; 4 = 4; 5 = 5; 6 = 6; 7 = 7; 8 = 8; 9 = 9; 0 = 10; A = 11; B = 12; C = 13; D = 14; E = 15; F = 16; G = 17; H = 18; I = 19; J = 20; K = 21; L = 22; M = 23; * = group centroid.

The four characters which contribute most to the first three canonical variate functions are given in Table 7. All the Western Australian taxa (excluding group A) have the inner surface of the calyx hairy. The analysis was repeated deleting character KHDI, to evaluate the importance of this character in determining this division into two major groups. As can be seen from figure 7, this basic delimitation is maintained. The specimens of the Western Australian groups (groups E-K & M) (Figs 6 & 7) have tended to separate into several clusters. The remaining specimens have also tended to form several clusters.

Table 7. Standardized canonical variate function coefficients for the four most important characters, for the first three functions.

Function	Character	Standardized canonical variate function coefficient
1	KHDI	-0.76520
	KGDO	-0.41096
	INTER	0.33935
	LKLP	-0.16367
2	LPLL	0.71354
	AAL	0.37924
	LLWL	-0.33051
	STMX	-0.30192
3	KHDO	0.71665
	LKLP	0.59342
	KHDI	-0.22818
	KL	-0.19023

However, these groups are not resolvable into clearly separable clusters (at least on the first two functions) because of scaling limitations. Therefore, the infrastructure of these groups is dealt with separately so as to improve resolution. However, a simplification of the infrastructure was achieved by a consideration of the canonical variate [discriminant] distances between group centroids. A modification of the original computer program DISCD (written by P. Lang, Adelaide University) was used to compute euclidean distances in D-space between all pairs of group centroids (using the canonical variate functions for group means). The length of the line between any two centroids (measured in discriminant units) being equal to the square root of Mahalanobis' D^2 . The nearest-neighbour phenogram (modification of 'Single linkage clustering' of Florek *et al.* 1951a, 1951b; and Sneath 1957) (Fig. 8) which was generated from the canonical variate distance matrix, summarizes the distances between the various group centroids. The advantage of the computed distance metric is that it is a summation of all the character differences, whereas the canonical variates are only concerned with characters which distinguish groups. The most serious limitation of this phenogram is that the distances are based on the means of the various groups when the critical delimitation of complexes should take into consideration the 'boundary' and extent of overlap (if relevant) between the various taxa. It must be remembered that distances based on group centroids could be potentially misleading because they may over-emphasize the distinctness of groups. However, the nearest-neighbour phenogram does assist in the interpretation of the canonical variate scattergram.

The determination of the number of taxa which should be recognized in a distance (dis-similarity) based phenogram is a major problem in numerical taxonomy. Sokal & Sneath (1963) advocated the use of a phenon line. They nominated all groups produced by that line as phenons. Unfortunately, the relationship between phenons and taxa is frequently rather obscure. However, one of the most serious objections to this technique is that, without some prior understanding of the taxonomy of the group being investigated, there

is no way to predict where the phenon lines should be placed. Furthermore, unless the fusion strategy used is strictly space conserving, the drawing of phenon lines is invalid due to group-size dependence (Clifford & Williams 1973; Clifford, in Williams 1976). Ratkowsky & Lance (1978), using the Cramér measure (Cramér 1946) for the degree of association, developed a criterion for determining the 'optimum' number of groups in a phenogram without requiring prior knowledge of the taxonomy of the specimens concerned. However, they still required the application of the phenon line to determine the groups for which the Cramér measure is calculated. Hill (1981) modified the Ratkowsky & Lance criterion so as to overcome the invalid use of phenon lines. Although

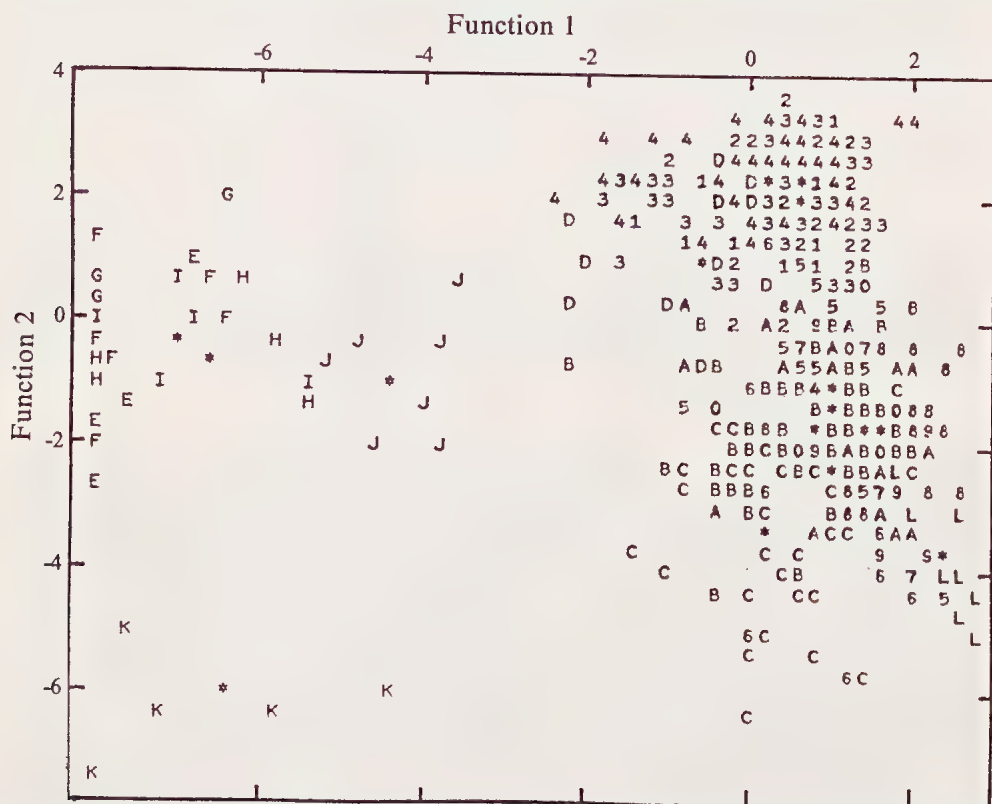


Fig. 7. Canonical variate scattergram (function 1 versus function 2) of 22 groups of the *P. aspalathoides*, *P. calycina*—*P. microphylla*—*P. serpyllifolia*, and *P. laricoides* complexes with KHDI character deleted from the analysis. For details of the taxa refer to Figs 5 & 6, however note in this figure that groups 17 and 23 are collectively designated by the letter 'G'.

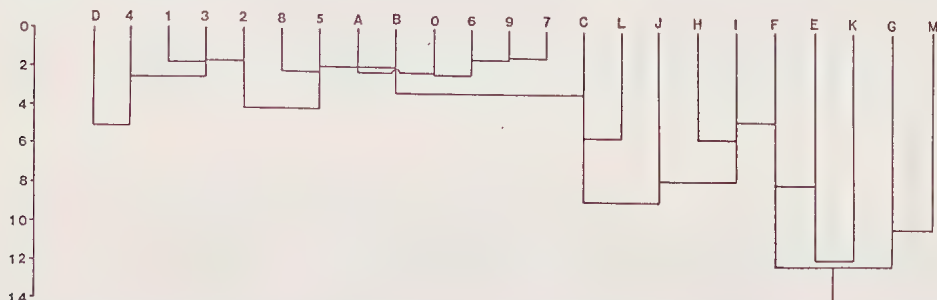


Fig. 8. Nearest-neighbour phenogram generated from the Canonical variate distance matrix of the initial 23 groups. For details of the taxa refer to Figs 5 & 6.

Hill's modification appears to improve the estimation of the number of groups in a phenogram, his criterion was unable to distinguish the specimens of *Pittosporum rhombifolium* (Pittosporaceae) from *Tristania conferta* (Myrtaceae) (refer Hill 1980), two unrelated taxa. Therefore, it seems doubtful that his criterion would be of any value when dealing with closely related taxa, as found in species complexes. Neither criteria were used to determine the number of taxa. Rather, the classification of replicate samples (as used by Sandland & Young 1979; Johnson 1982) was used to decide subjectively the number of taxa which should be recognized.

Based on distances, the Western Australian groups (excl. group A) remain distinct from the other groups (Fig. 8). Furthermore, the relatively distinct clusters within the Western Australian specimens (Fig. 6) are supported by the relatively large distances between the centroids of these groups (Fig. 8). The homogeneity of the other groups (Fig. 6) is verified by the variance of distance values being quite low, as shown in figure 8. However, the structure of the groups is clearer in the phenogram (Fig. 8). Groups 1-4 are very similar to each other and, on the basis of nearest-neighbour distances, appear to represent one taxon (*P. aspalathoides*) (Fig. 8). This is also supported, but less clearly by the canonical variate scattergram (Fig. 6). Group D (*P. florifera*) is most similar to *P. aspalathoides* (groups 1-4) (Fig. 6); however, the former appears to be a distinct taxon on the basis of the nearest-neighbour distances (Fig. 8). Groups 5-B and possibly C appear to represent another taxon (*P. serpyllifolia*), whereas group L. (*P. calycina*) is quite distinct from the previous groups on the basis of distance values. The distinctness of

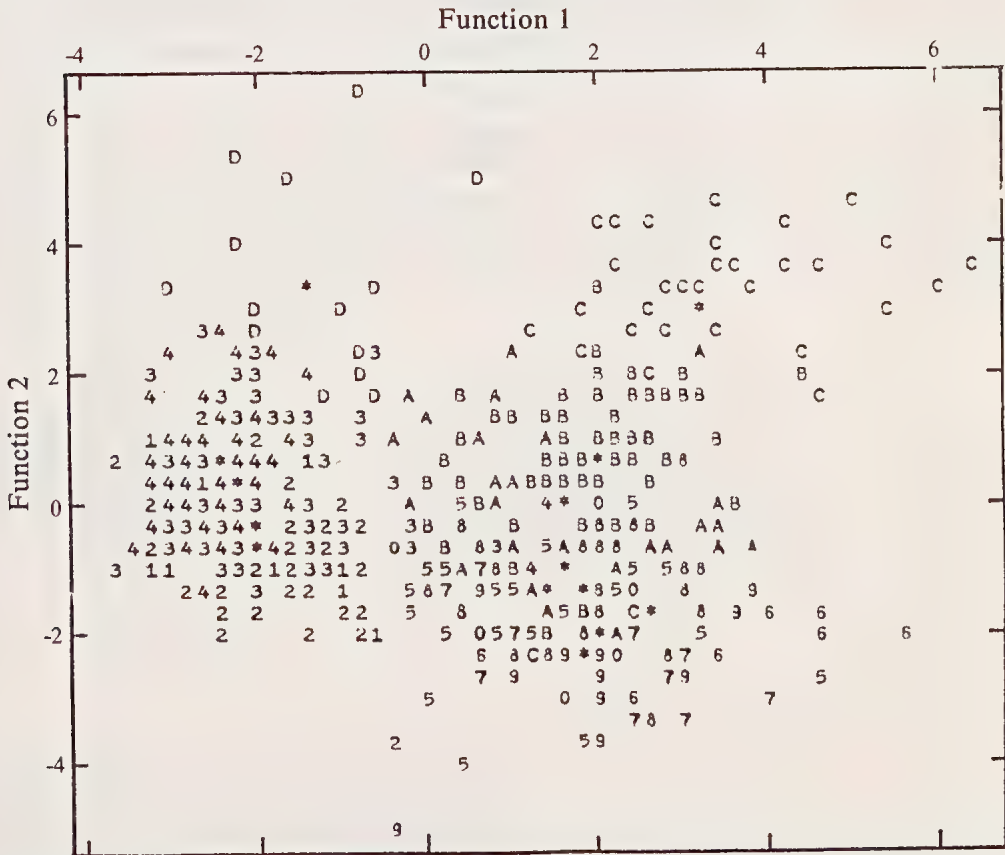


Fig. 9. Canonical variate scattergram (function 1 versus function 2) of the first fourteen taxa (Taxa 1 to D). For details of the taxa refer to Figs 5 & 6.

groups 1-4 from groups 5-C was also evaluated using canonical variate analysis by (1) only including specimens of groups 1-D (Fig. 9), and by (2) only including specimens of groups 1-8 (Fig. 10). The increased scaling improved the resolution such that groups 1-4 (*P. aspalathoides*) is regarded as distinct from groups 5-C (*P. serpyllifolia* (particularly evident in Fig. 10), and that group D (*P. florifera*) is a distinct taxon (particularly evident in Figs 6 & 7, also refer p. 312. The Western Australian groups (excl. group A) represented a distinct entity (refer Figs 6 & 8) which was studied in more detail (see below).

Scattergrams of functions 1 and 3 (not presented here) further supported the distinctness of the above groups.

A number of computer programs were used in the following detailed analyses of the morphological variation within each of the above species and species complexes. Some of these programs have been discussed in the previous section (e.g. those used for canonical variate analysis and principal component analysis).

The data (of the original 23 characters) were standardized by range ($0 \leq \text{character state} \leq 1$) so as to minimise the effect of isolated strongly deviant values. The population means for each character were weighted by the *F*-1 value (Adams 1975). All characters with *F* values less than 1 (at the 0.01 level) were not used in subsequent analyses.

A matrix of Manhattan metric distances was calculated between the individuals [using program TAXDT (refer Whiffin 1978), which utilizes the $d_1(j, k)$ formulation of Sneath and Sokal 1973]. Williams and Clifford (in Williams 1976) showed that the Manhattan metric measure, using range-standardized data, is less affected by 'out-lying' values than some other measures (e.g. Bray-Curtis measure). This matrix was then used to group the populations, using the overall similarity of the individual specimens, in the form of hierarchic non-overlapping clusters. This was graphically presented as a phenogram.

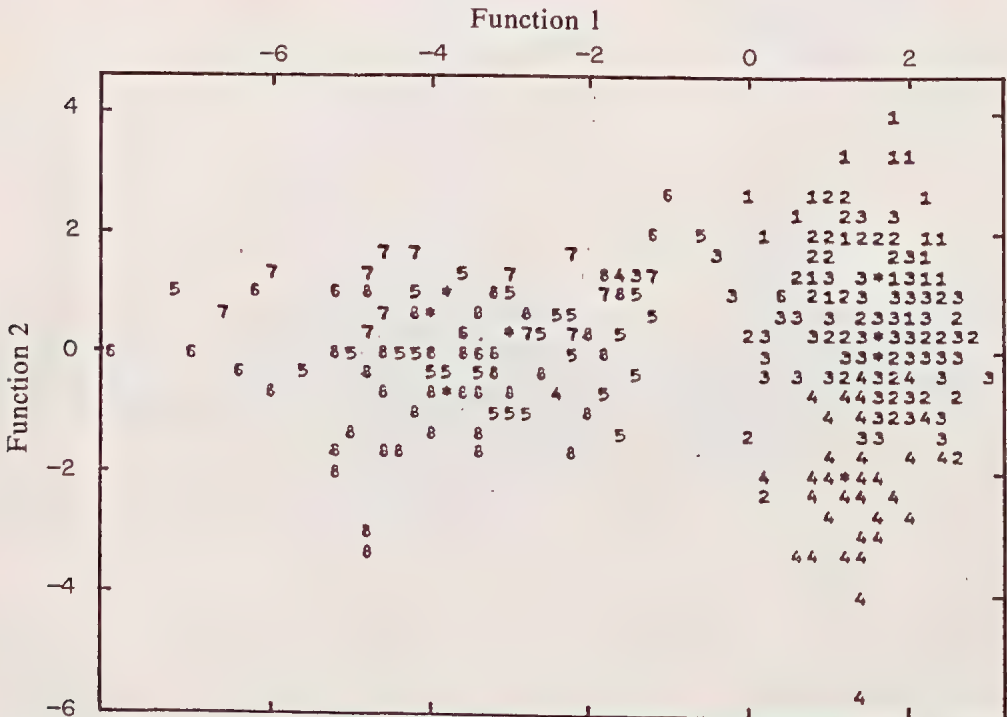


Fig. 10. Canonical variate scattergram (function 1 versus function 2) of the first eight taxa (Taxa 1 to 8). For details of the taxa refer to Figs 5 & 6.

The matrix was subjected to a principal coordinates analysis (Gower 1966, 1967, 1969) (using programs GOWORD or GOWER—refer Williams *et al.* 1971) to produce an ordination of the individuals. The results of this ordination were graphically presented (using program ORDX—refer Whiffin 1978).

The above methods used all available characters (with F values greater than 1, at the 0.01 level) to determine the phenetic relations among the populations.

Numerical analysis of *Prostanthera aspalathoides*

The canonical variate scattergrams (Figs 7, 9 & 10) and the nearest-neighbour phenogram (Fig. 8) suggest that *P. aspalathoides* is very homogeneous, with the Kangaroo Island populations (population 4—refer Figs 8 & 10) slightly distinct from the other specimens. The infraspecific structure of *P. aspalathoides* was examined in more detail. 190 specimens from 22 populations were analysed (Fig. 20). The number of specimens in each population and the localities of each population are listed in Table 9. Using principal component analysis, the characters exhibiting high component scores (on the first three components) included INTER, LL, LLW, BL, BLW, LLKP, KL, STHL, STBB, STMX (refer Figs 11 & 12). Therefore these characters contribute most to the total variance of the specimens. STHL and STMX were highly intercorrelated on all components and so STMX was deleted from subsequent analyses. KHDI was also deleted because it was invariant within this species. Canonical variate analysis of the 22 populations produced some clustering on the first two functions (Fig. 13). The Kangaroo Island specimens (I, J) form a weakly distinct cluster. Similarly, the population from Bordertown, Kiata, and the Little Desert (A, 9, 0, respectively) also form a more or less distinct cluster. Only 50.7% of the specimens were correctly classified (according to the canonical variate classification results, refer Nie *et al.* 1975). This low value is to be expected since it would not be realistic to expect each population to be distinct. Although classification results are frequently of minimal value, especially in this type of situation, the result of the reclassification of the populations may (indirectly) indicate relationships. For example, in most cases the reclassification was to a nearby population. However, with respect to the Cobar (1) population, 75% of the specimens were correctly classified, with the other 25% of the specimens being reclassified with the Cowell (K) population; 25% of the Condobolin (2) population was also reclassified with the Cowell (K) population.



Fig. 11. Principal components plot (component 1 versus component 2) of the character set of *P. aspalathoides*. 1 = INTER; 2 = STHD; 3 = STGD; 4 = LL; 5 = LLW; 6 = LLWL; 7 = LHD; 8 = LGD; 9 = PL; 10 = BL; 11 = BLW; 12 = LKLP; 13 = KL; 14 = KLLT; 15 = KHDO; 16 = KGDO; 17 = KHDI; 18 = AAL; 19 = STHW; 20 = STHL; 21 = STBB; 22 = STMX. For details of characters refer Table 1.

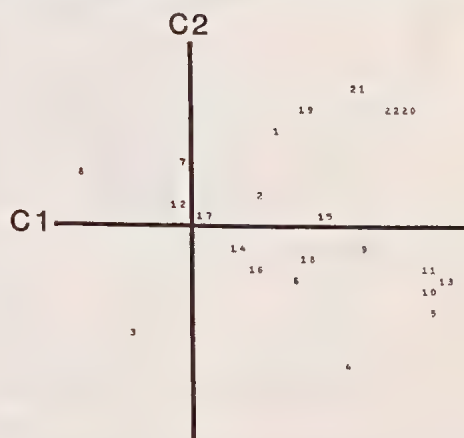


Fig. 12. Principal components plot (component 2 versus component 3) of the character set of *P. aspalathoides*. For details of characters refer Fig. 11 and Table 1.

The first four axes of the principal coordinates analysis accounted for only 31% of the total variation. Therefore, these ordinations provided a simplification of the data which is of limited value. The ordination on these axes produces relatively indistinct clusters. The Kangaroo Island populations are weakly distinct from the mainland populations on most axes (Fig. 14-T, U). Similarly, the Cobar (A), Condobolin (B), West Wyalong (C) and Rankin Springs (D) populations are weakly distinct. However overall, principal coordinates analysis did not provide a useful simplification of the data. Similar results were obtained using the Q-technique of principal component analysis. Furthermore, single-linkage, nearest-neighbour and furthest-neighbour phenograms, generated from the matrix of the Manhattan metric distances, provided little additional information and their complexity reduced their ability to provide a visual simplification of the data.

Therefore, since the morphological variation within *P. aspalathoides* is more or less continuous, a formal infraspecific classification is not proposed. This morphological variation is discussed in more detail in the 'Geographic Variation' chapter.

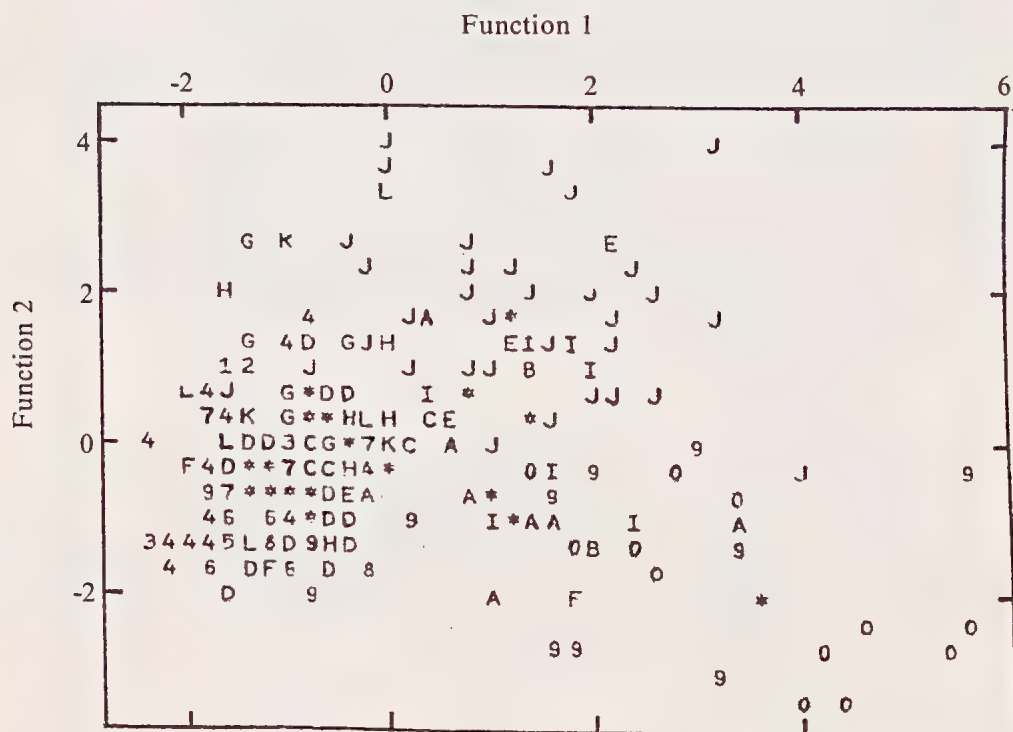


Fig. 13. Canonical variate scattergram (function 1 versus function 2) of *P. aspalathoides*. For details of taxa refer Table 8. 1 = 1; 2 = 2; 3 = 3; 4 = 4; 5 = 5; 6 = 6; 7 = 7; 8 = 8; 9 = 9; 0 = 10; A = 11; B = 12; C = 13; D = 14; E = 15; F = 16; G = 17; H = 18; I = 19; J = 20; K = 21; L = 22; * = group centroid.

Numerical analysis of the *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex

Prostanthera serpyllifolia and *P. calycina* are confined to South Australia, whereas *P. microphylla* occurs in New South Wales, Victoria, South Australia and southern Western Australia. The Victorian populations of the latter species are very homogeneous,

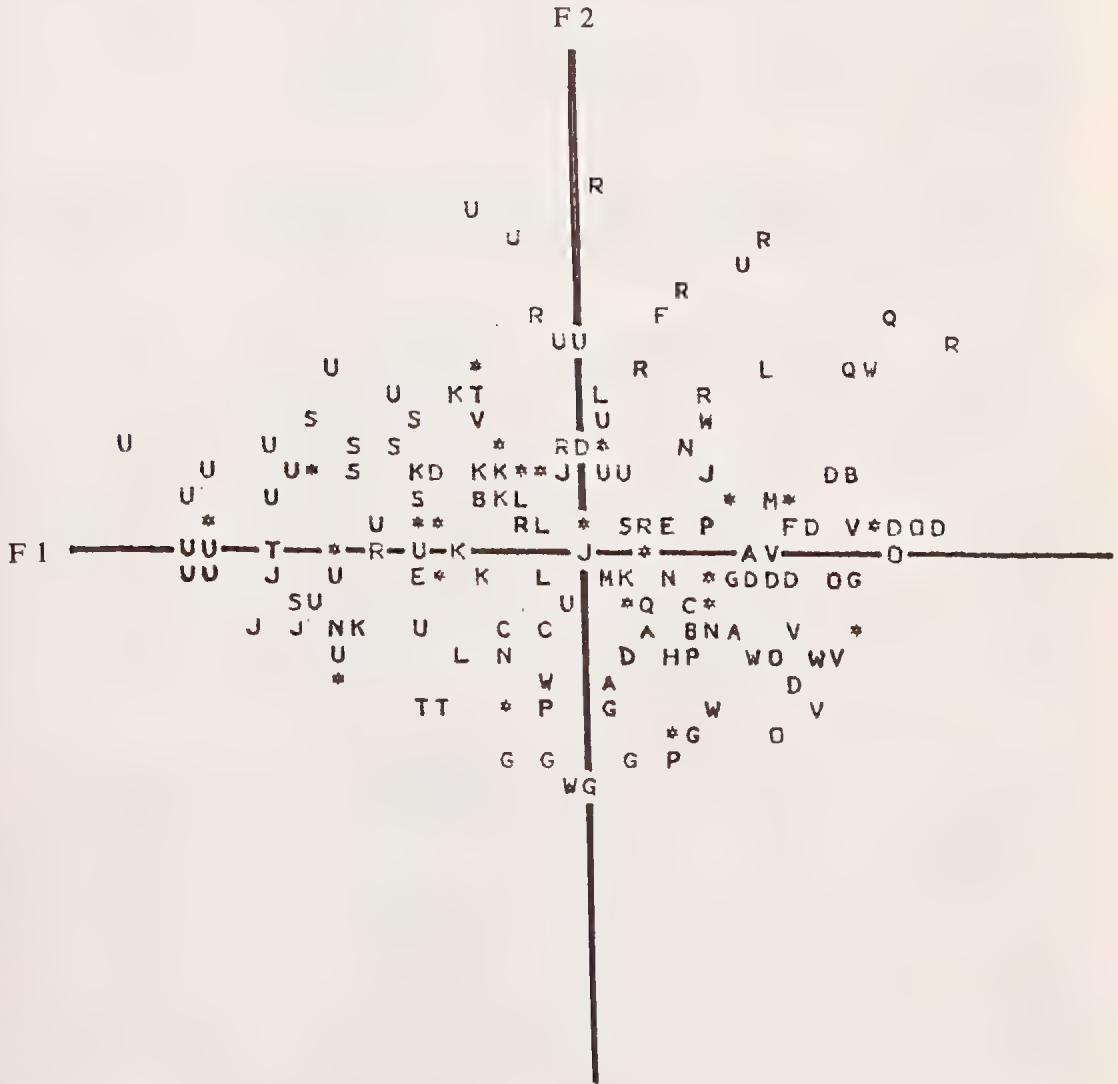


Fig. 14. Principal coordinate plot (function 1 versus function 2) of the populations of *P. aspalathoides*. A = Cobar; B = Condobolin; C = West Wyalong; D = Rankin Springs; E = Borellan; F = Balranald; G = Bendigo; H = Wyperfeld; J = Kiata; K = Little Desert; L = Bordertown; M = Scorpion Spring; N = Billiatt; O = Overland Corner; P = Walker Flat; Q = Coomandook; R = Braendler's Scrub; S = Goolwa; T = American River; U = Kingscote; V = Cowell; W = Whyalla; * = two or more individuals from different groups, if from same group then group symbol printed.

all having the calyx hairy on the outer surface, plus an anther appendage. In New South Wales, in the Murray Lands of South Australia, and in Western Australia, the populations are less homogeneous, but are still readily distinguishable from closely related taxa. However, *P. microphylla* from Eyre Peninsula (South Australia) is extremely variable and is frequently difficult to distinguish from *P. serpyllifolia*, and to a lesser extent, from *P. calycina*. The Moonta population (on Yorke Peninsula, South Australia) is typical of much of the collections (of *P. microphylla*) from New South Wales and Victoria. Therefore, this population was included in this study so that a comparison between the Eyre Peninsula populations and those of the eastern States could be made. The Kangaroo Island populations (5-8) were included so as to facilitate an evaluation of the distinctness of these populations from the mainland specimens. 156 specimens from 14 populations were analysed (Fig. 27). The number of specimens in each population and the localities of each are listed in Table 10.

The nearest-neighbour phenogram (based on all characters except KHDI) generated from the matrix of the Manhattan metric distances is presented in figure 15 (for details of collection refer Table 8). The complexity of this phenogram reduces its ability to provide a visual simplification of the data. However, it does provide some information on the infra-structure of this complex.

The various populations represented in this phenogram (Fig. 15) are clearly heterogeneous (*cf.* the duplicates of *Eichler 15172*, and the population collections of *Conn 684, 1073, 1077-1079, 1089-1091, 1093, 1096 & 1097*). However, the Stenhouse Bay population is relatively distinct from the other populations even though there is a close relationship with several of the Port Lincoln specimens. The distinctiveness of this population is also suggested in figures 8 & 9. The Stenhouse Bay population is composed of individuals which are glabrous or very sparsely hairy with a very high glandular density on most organs. They also have more or less shiny leaves which are often thickened. However, this form is regarded as environmentally induced (p. 256). The distinctiveness of the genotype is unknown; however when additional collections (not used in the numerical analyses) from further inland are considered, these collections tend to be intermediate between the more typical *P. serpyllifolia* ssp. *serpyllifolia* and this local form. Therefore, the Stenhouse Bay form is not given formal taxonomic status.

The only other populations which are relatively distinct from the other specimens are the Venus Bay and Streaky Bay populations (Fig. 15, specimens 151-156). The specimens from these two populations belong to *P. calycina*. They tend to be very hairy on the branches and have relatively large calyces. The hairs are simple, stiff, straight and appressed such that the hair apex is directed towards the distal part of the relevant organ (Fig. 60C). When additional specimens (not included in the numerical analyses) are considered, these specimens remain distinct from *P. serpyllifolia*. *P. calycina* grows under a different set of environmental factors to that of *P. serpyllifolia* (pp. 257-262). Hence it is not unexpected that there is also a different phenotypic response to these factors. However, this taxon appears to be genetically distinct since there are a few collections of *P. serpyllifolia* occurring sympatrically with *P. calycina* at Venus Bay. Furthermore, cultivated material of this species at the Burrendong Arboretum (N.S.W.) (*Conn 793*) has retained its phenotypic distinctness from *P. serpyllifolia*. Therefore, *P. calycina* is maintained as a distinct species.

Although certain individual specimens are very distinctive (Fig. 15) the overall homogeneity of the morphological variation of the specimens (also refer Figs 8-10) suggest that *P. microphylla* cannot be maintained as a distinct species from *P. serpyllifolia*. However, this taxon can usefully be recognized as a subspecies of *P. serpyllifolia*, even though some specimens appear intermediate between the two subspecies. The key differences between these subspecies are summarized in the key to the subspecies of *P. serpyllifolia* (p. 293).

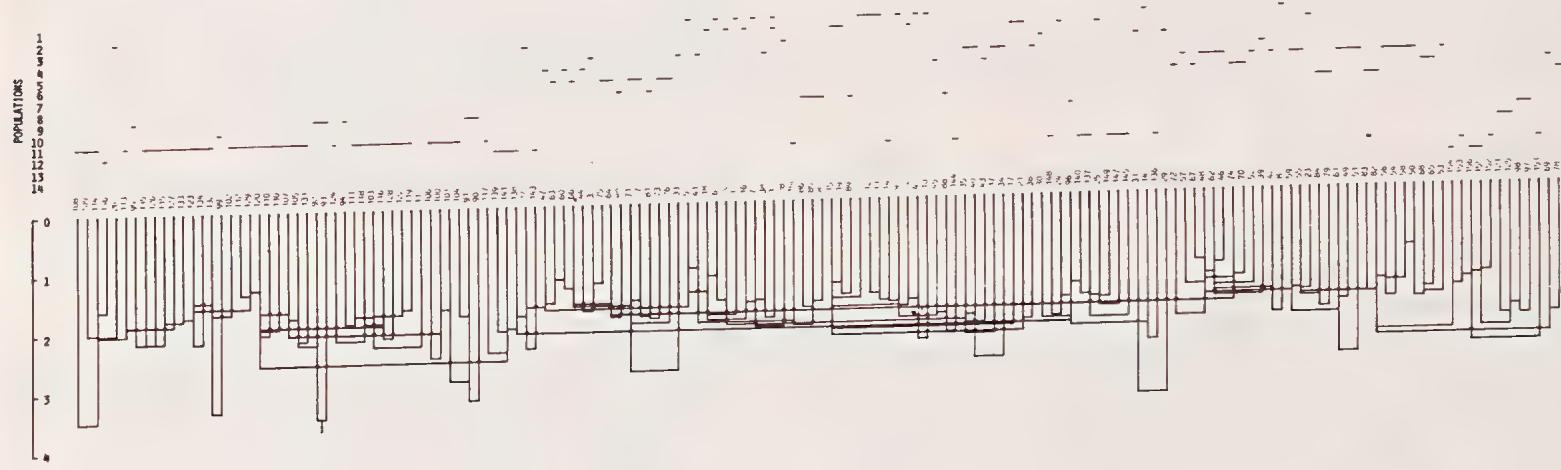


Fig. 15. Nearest-neighbour phenogram (based on all characters except KHD1) generated from the Manhattan distance matrix of 156 specimens of the *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex. Population numbers are: 1 = Kimba; 2 = Arno Bay; 3 = Lock; 4 = Moonta; 5 = Cape Borda; 6 = Kelly Hill Cave; 7 = Mt Taylor; 8 = Cape Cassini; 9 = Port Lincoln; 10 = Mt Greenly; 11 = Stenhouse Bay (Innes National Park); 12 = Hinks Conservation Park; 13 = Venus Bay; 14 = Streaky Bay. The numbers directly above the phenogram refer to the specimens (refer Table 8 for details of collectors and collection numbers).

Table 8. Details of the 156 collections used in the numerical analyses of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex.

1. Hill 652	53. Conn 1077e	105. Copley 4424
2. Whibley 279	54. Conn 1080	106. Lothian 2638
3. Eichler 19193	55. Conn 1078a	107. Blaylock 70
4. Canning CBG 23620	56. Conn 1078b	108. Copley 4619
5. Phillips CBG 23621	57. Conn 1078c	109. Jackson 2641
6. Orchard 2138	58. Conn 1079a	110. Blaylock 1092
7. Beaulehole 17575	59. Conn 1079b	111. Carrick 3907
8. Rohrlach 625	60. Conn 1079c	112. Carrick 3913
9. Orchard 2138	61. Eichler 15172 (UC)	113. Carrick 3904
10. Rohrlach 158	62. Eichler 15172 (AD)	114. Carrick 3905
11. Rosier 59	63. Conn 1089a	115. Carrick 3903
12. Hilton s.n., 27.viii.1955	64. Conn 1089b	116. Carrick 3902
13. Caulfield 236	65. Conn 1089c	117. Carrick 3901
14. Wilson 236	66. Conn 1090a	118. Carrick 3906
15. Tindale 463	67. Conn 1090b	119. Carrick 3908
16. Ising s.n., 27.viii.1935	68. Conn 1090c	120. Carrick 3909
17. Alcock 631	69. Conn 1091a	121. Carrick 3910
18. Whibley 1992	70. Conn 1091b	122. Carrick 3911A
19. Tindale 463	71. Conn 1091c	123. Carrick 3911B
20. Eichler 19171	72. Jackson 376	124. Carrick 3912
21. Whibley 7435	73. Eichler 15490	125. Copley 4425
22. Alcock 632	74. Eichler 18538	126. Hill 1080
23. Ising s.n., 27.viii.1935	75. Conn 1093a	127. Hill 1078
24. Barker 3639A	76. Conn 1093b	128. Copley 4423
25. Barker 3639B	77. Conn 1093c	129. Blaylock 1124
26. Barker 3639C	78. Conn 1096a	130. Heyligers 80127
27. Phillips CBG 23546	79. Conn 1096b	131. Smith 779
28. Phillips CBG 23846	80. Conn 1096c	132. Kraehenbuehl 864
29. Puckridge s.n., anno. 1962	81. Conn 1097a	133. Alcock 4539
30. Tindale 590	82. Conn 1097b	134. Spooner 6171
31. Phillips CBG 23783	83. Conn 1097c	135. Copley 4897
32. Gill 152	84. Jackson 852	136. Cleland s.n., 12.viii.1964
33. Beythieu 92	85. Conn 1073a	137. Symon 6158
34. Beythieu 91	86. Conn 1073b	138. Wheeler 801
35. Phillips CBG 23839	87. Conn 1073c	139. Alcock 2202
36. Donner 1871	88. Conn 1073d	140. Cleland s.n., 17.ix.1966
37. Copley 4091	89. Conn 1073e	141. Wheeler 748
38. Copley 770	90. Browne s.n. (MEL)	142. Symon 6319
39. Phillips CBG 31378	91. Specht 2706	143. Symon 6192
40. Copley 2285	92. Wilson 410	144. Symon 6320
41. Tepper s.n., anno. 1874	93. Wilson 411	145. Symon 6426
42. Eichler 15172 (NSW)	94. Anon. (AD966032930)	146. Alcock 2351
43. Eichler 15172 (MEL)	95. Whibley 1961	147. Alcock 1568
44. Cleland s.n., 2.ii.1948	96. Ising s.n., 17.x.1936	148. Cleland s.n., 10.vi.1965
45. Kirkpatrick s.n., -.xii.1968	97. Conn 684A	149. Specht 2067
46. Phillips s.n., 28.ix.1965	98. Conn 684B	150. Wheeler 888
47. Eichler 15172 (E)	99. Conn 684C	151. Warburton s.n. (MEL)
48. Wheeler 1308	100. Hill 1079	152. Willis s.n., 26.viii.1947
49. Conn 1077a	101. Copley 4519	153. Dennis 170
50. Conn 1077b	102. Copley 4520	154. Weber 6210
51. Conn 1077c	103. Weber 4254	155. Wrigley CBG 36640
52. Conn 1077d	104. Weber 4342	156. Copley 4858

Numerical analysis of the *Prostanthera laricoides* complex

Canonical variate analysis of the 8 populations of the *P. laricoides* complex (Fig. 34) produced distinct clustering on the first two functions (Fig. 16). Populations 1, possibly 3, 4, 7 and 8 are distinct from each other, whereas populations 2, 5 and 6 appear to represent a single group. On the first and third functions, populations 2, 5 and 6 were tightly clustered, whereas population 3 was distinct from the former group and less distinct from population 4. The nearest-neighbour phenogram of the canonical variate distances between group centroids (based on the square root of Mahalanobis' D^2) (Fig. 8) also emphasizes the distinctness of the above groups. It also suggests a close relationship between the Campion, Southern Cross and Mt Churchman populations (F, H & I [in Fig. 34 = 2, 5 & 6, respectively]). In the remaining discussion of this complex, I have included the taxonomic conclusions with the relevant population(s) when these are discussed, so that cross-referencing from the 'Systematic Treatment' to this section will be easier.

The nearest-neighbour phenogram of the individual specimens (based on a matrix of Manhattan metric distances of all characters except KHDI) (Fig. 17) allows for a more detailed evaluation of the infrastructure of these taxa than is possible using group centroids (Fig. 8). Populations 1 (*P. laricoides*), 3 and 4 (*P. incurvata*), and 8 (*P. patens*) are distinct. Populations 2, 5 and 6 (*P. semiteres*) plus population 7 (*P. pedicellata*), represent a closely related, although somewhat heterogeneous group.

The first three axes of the principal coordinate analysis provide a useful simplification of the data because they account for 50.87% of the total variation. The ordination on these axes produces relatively distinct clusters. Population 8 (*P. patens*) is very distinct on all functions (e.g. function 1 versus 2 [Fig. 18] and functions 2 versus 3 [Fig. 19]). Populations 1,

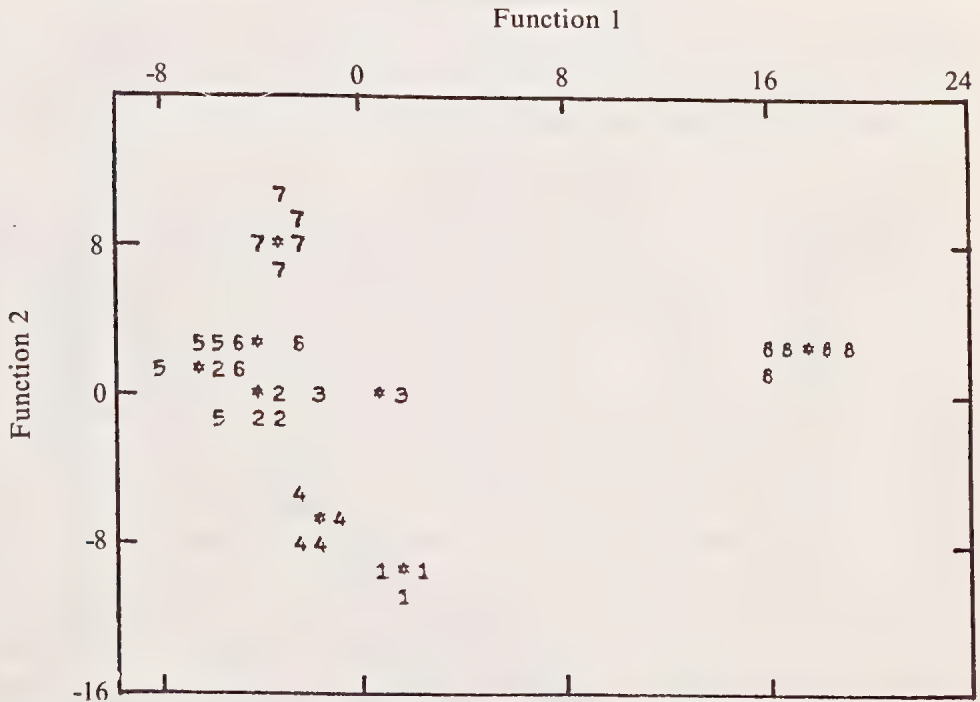


Fig. 16. Canonical variate scattergram (function 1 versus function 2) of the 8 populations of the *P. laricoides* complex. For details of the populations refer Fig. 34 and Table 11.

3 and 4 form a distinct group on functions 1 versus 2 (Fig. 19), with *P. laricoides* (1) clearly distinct from *P. incurvata* (3 & 4) on functions 1 versus 2 (Fig. 18) and 2 versus 3 (Fig. 19). Populations 2, 5-7 form a single separate cluster on the first three functions (Figs 18 & 19). Populations 2 and 5 (*P. semiteres* ssp. *semiteres*) are indistinct on all functions. Populations 6 (*P. semiteres* ssp. *intricata*) is distinct on the first three functions (Figs 18 & 19), but indistinct on most other functions. Although population 7 (*P. pedicellata*) is closely related to population 6 (*P. semiteres* ssp. *intricata*), the ordination maintains the former as a distinct group (Figs 18 & 19).

I have recognized five species in this complex (viz. *P. incurvata*, *P. laricoides*, *P. patens*, *P. pedicellata*, and *P. semiteres*). The outer surface of the calyx is glabrous in *P. incurvata* and *P. semiteres*, whereas the other species are normally hairy on the outer surface of the calyx. *P. pedicellata* has a long pedicel (7-13 mm long) and lacks an anther appendage, whereas *P. patens* and *P. laricoides* have pedicels less than 3.5 mm long and they have an anther appendage. These latter two species can be distinguished from each other by *P. patens* having small leaves (less than 2 mm long), whereas *P. laricoides* has leaves at least 10 mm long. *P. incurvata* has hairy branches (rarely glabrous) with pedicels up to 2 mm long and usually incurved leaves which distinguish it from *P. semiteres*. *P. semiteres* has glabrous branches (rarely with an occasional hair) with pedicels 3-15 mm long and more or less straight leaves.

With the exception of *P. patens*, the *P. laricoides* complex is made up of closely related species. *P. patens* has its closest affinities with *P. serpyllifolia*, whereas the affinities of the remaining species appear to be with *P. aspalathoides*.

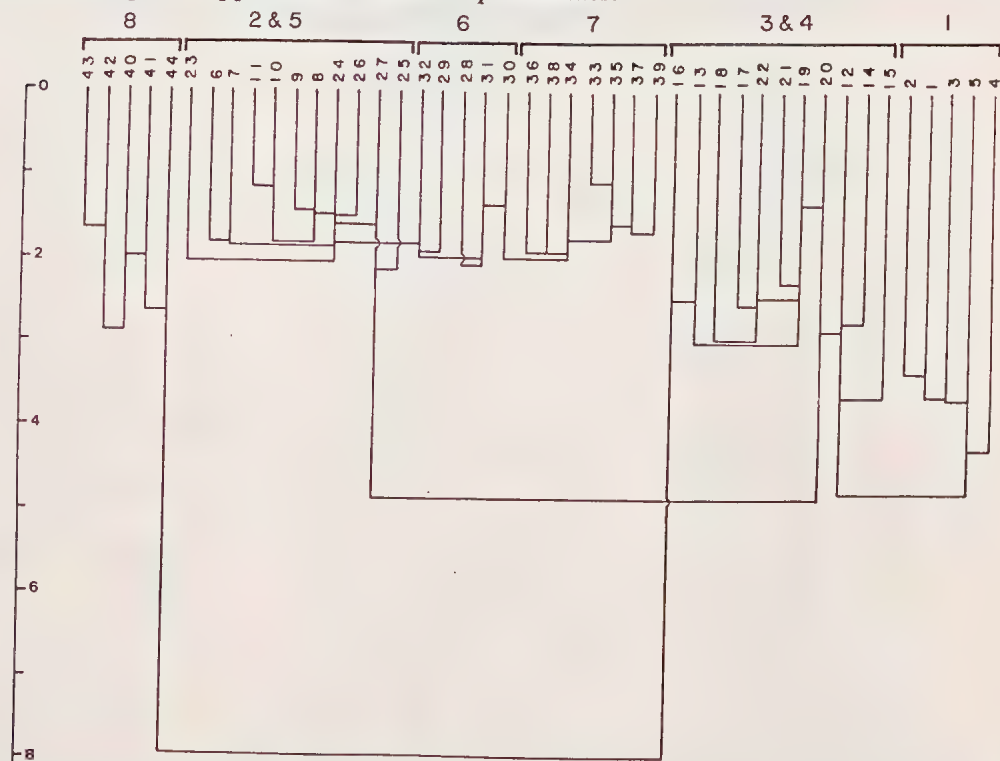


Fig. 17. Nearest-neighbour phenogram generated from the Manhattan distance matrix of the 44 specimens of the *P. laricoides* complex (based on all characters except KHDI). Population numbers (as used in Table 11 and Fig. 34 are given above the brackets. The numbers directly above the phenogram refer to the specimens (refer Table 12 for details of collectors and collection numbers).

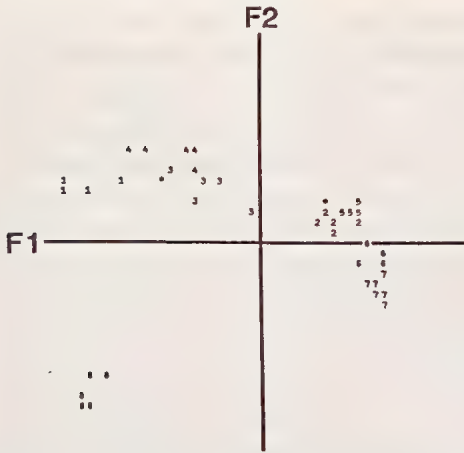


Fig. 18. Principal coordinate plot (function 1 versus function 2) of the populations in the *P. laricoides* complex. 1 = Cundeelee; 2 = Campion; 3 = Lake Cowan; 4 = Kalgoorlie; 5 = Southern Cross; 6 = Mt Churchman; 7 = Pindar; 8 = Paynes Find; * = Two or more individuals from different groups, if from same group then group symbol printed. For further details of populations refer Fig. 34 and Table 11.

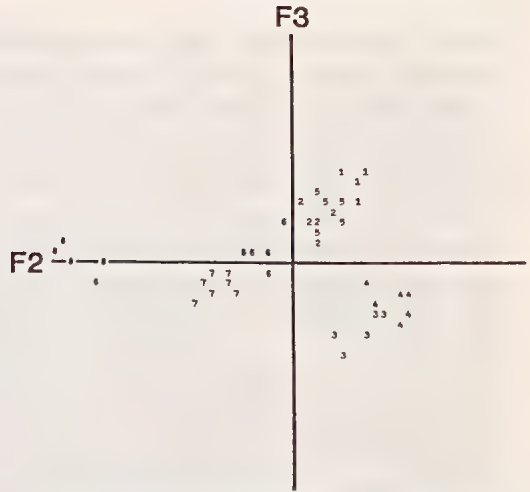


Fig. 19. Principal coordinate plot (function 2 versus function 3) of the populations in the *P. laricoides* complex. 1 = Cundeelee; 2 = Campion; 3 = Lake Cowan; 4 = Kalgoorlie; 5 = Southern Cross; 6 = Mt Churchman; 7 = Pindar; 8 = Paynes Find; If two or more individuals from the same group have the same coordinates then group symbol printed. For further details of populations refer Fig. 34 and Table 11.

Geographic variation

Geographic variation is the 'pattern of variation present within a species over its entire range' (Whiffin 1978). The detailed analysis of geographic variation often provides useful information, especially amongst closely related taxa, on the pattern of variation present, on possible modes of speciation, and on the historical biogeography and lines of migration of the taxa.

Geographic variation is the resultant complex response of many characters to a variety of interdependent environmental and genetical factors. Hence it is a multidimensional process (Fisher 1968). The factors determining and limiting the pattern of distribution of a taxon, within its range, are quite different from those factors which control the extent of its total geographic range. For example, certain ecological factors result in a taxon having a complex mosaic pattern of variation within its total range. Since geographic variation is complex, any study of such variation may benefit by the use of various numerical and statistical procedures to simplify and assist in the visualization of the overall pattern of variation.

Several computer programs, which have been variously modified (written in Fortran 77 [version 5] {Meissner & Organick 1980} for use on the CDC Cyber 173 {CDC. 1981, Fortran version 5 Reference manual, Publ. no. 6048130}, at the University of Adelaide) were used to perform the various analyses (for details also refer Whiffin 1978, 1982a). Initially, the original 23 characters were standardized by range ($0 \leq \text{character states} \leq 1$) so as to minimise the effect of large, isolated ('outlying') values. Although not presented here, standardization by standard deviation appeared to be equally useful. The population means for each character were computed and weighted by the *F*-1 value (Adams 1975). Since the specimens were divided *a priori* into groups (populations), the characters were weighted according to their utility for distinguishing among the groups. Those characters which had the most significant between-group variation carried the most weight in the subsequent analyses. All characters with *F* values less than 1 (at the 0.01 level) were rejected and were not used in subsequent analyses. The data was also subjected to the Student-Newman-

Keuls (SNK) multiple range procedure (Adams 1969, 1970b, 1972a; Sokal 1965; Sokal & Rohlf 1969) (using program SNK) to determine which population means were significantly different (at the 0.01 level). The population means of those characters that were significantly different between populations (at the 0.01 level) in both the F test and the SNK test were contoured using surface trend analysis (Adams 1970b, 1970c, 1972a, 1974; Krumbein 1962; Marcus & Vandermeir 1966; Sokal 1965; Turner 1970; Whiffin 1978) (using program CONTRS). Although valuable information concerning geographic variation can be obtained by the consideration of each character separately, it is in general, more useful and more valid to consider all characters (which are significant for both the F test and the SNK test) simultaneously (Whiffin 1978). The multivariate approach is more valid because geographic variation is generally the result of many environmental and genetical factors acting upon the whole genotype. Differential systematics was used (Adams 1970c, 1972a; Hagmeir 1958, Womble 1951). This a multivariate method which maps the composite differential produced by Adams (1970c). Differential systematics gives an indication of the total trend of several characters simultaneously. The program DIFSYS (originally written by Adams 1969, 1970c) was used to produce the differential systematics, with the differentials for each character weighted according to their F ratios.

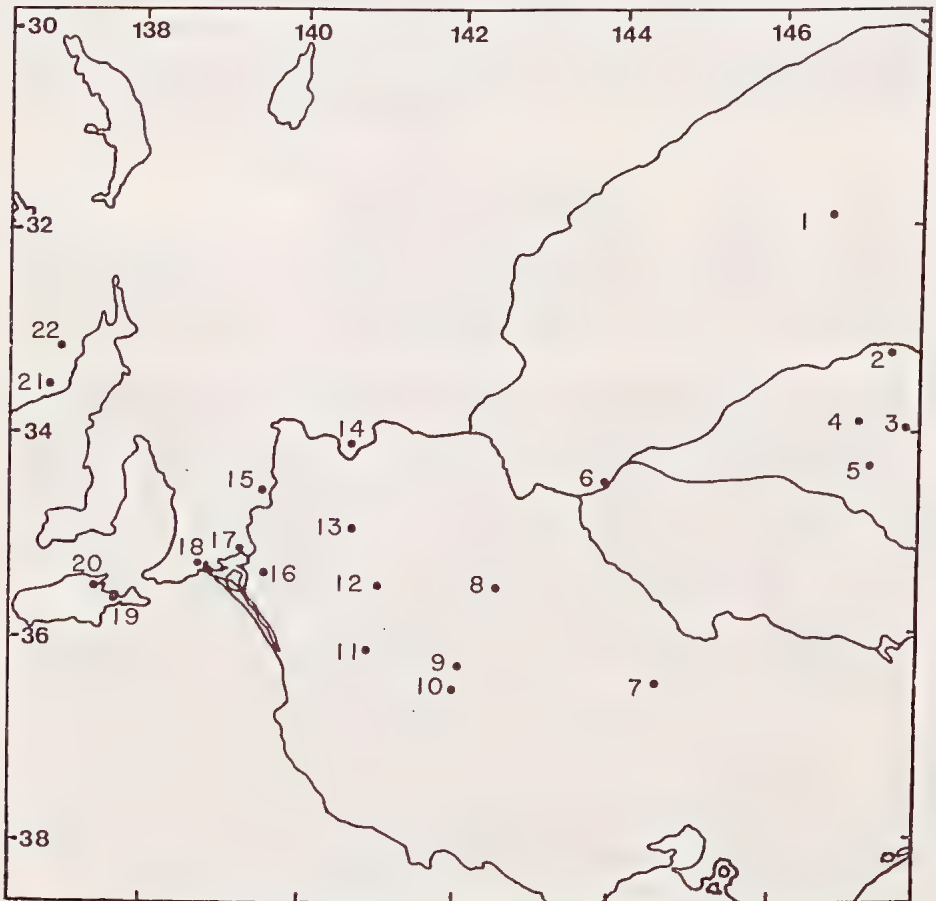


Fig. 20. Locality details of the 22 populations of *P. aspalathoides* used for morphological variation studies. For further details of populations refer Table 9.

Morphological variation in *Prostanthera aspalathoides*

P. aspalathoides occurs in New South Wales, Victoria and South Australia (Fig. 63). The single collection from St. George, Queensland (*R. Jordan s.n.*) was not included in this study because one collection could not be expected to represent satisfactorily the morphological structure of the St George population: 190 specimens from twenty-two populations were analysed (Fig. 20) (refer p. 211 for details of general procedure followed). For further details of these populations refer Table 9.

Of the original 23 characters, 16 showed both a significant *F*-test and a significant SNK test (both at the 0.01 level). Each of these 16 characters was contour-mapped (using program CONTRS). These contour maps show the major regional trends in population means for the characters presented (Whiffin 1978).

Based on the pattern of variation, it is possible to group the contour maps of the characters subjectively into a number of main types. Examples of contour maps of characters in these main types are provided in figures 21-25. A summary of the SNK test (for the relevant character) is provided under each contour map. Any two populations whose means are not underscored by the same line are significantly different for that character, but any two underscored by the same line are not highly significantly different (Sokal & Rinkel 1963; Sokal & Rohlf 1969; Adams 1970c). The populations are ranked in order of magnitude of means for each character. The population with the highest mean being recorded first (on left).

Table 9. Details of the 22 populations of *P. aspalathoides* used for morphological variation studies.

Population	Number of specimens/population
NEW SOUTH WALES	
1. Cobar	4
2. Condobolin	3
3. West Wyalong	7
4. Rankin Springs	15
5. Barellan	3
6. Balranald	7
VICTORIA	
7. Bendigo (Whipstick Mallee)	9
8. Wyperfeld National Park	4
9. Kiata	6
10. Little Desert (SE corner)	10
SOUTH AUSTRALIA	
11. Bordertown	10
12. Scorpion Springs National Park	3
13. Billiatt National Park	6
14. Overland Corner	10
15. Walker Flat	5
16. Coomandook	5
17. Braendler's Scrub (Monarto South)	12
18. Goolwa	11
19. American River	7
20. Kingscote	35
21. Cowell	8
22. Whyalla	10

The most common type of pattern of geographic variation is exemplified by the three characters 1) LL—length of lamina (Fig. 21), 2) LPLL—length of petiole to length of lamina ratio (Fig. 22), 3) LP—length of pedicel (Fig. 23). In figure 21, the Kingscote (20) and Little Desert (10) populations have the longest lamina. The populations with slightly shorter lamina (but not significantly different—refer SNK result, Fig. 21), in decreasing order, are Kiata (9), Goolwa (18), American River (19), Balranald (6), Braendler's (17), Bordertown (11), W. Wyalong (3) and Scorpion Springs (12). The more northerly populations of Cobar (1), Condobolin (2), Overland Corner (14), Whyalla (22) and Cowell (21), plus the Bendigo population (7) have short lamina. A similar pattern is found with

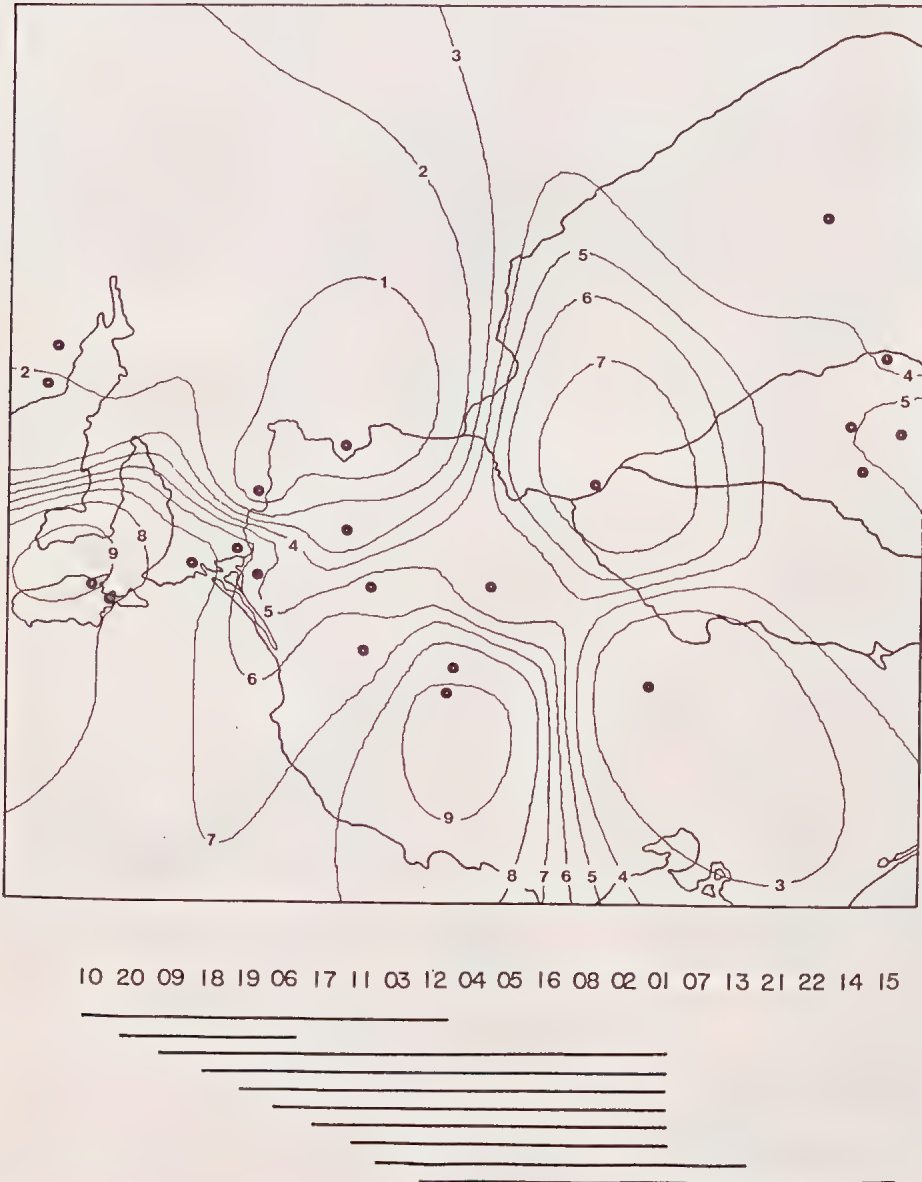
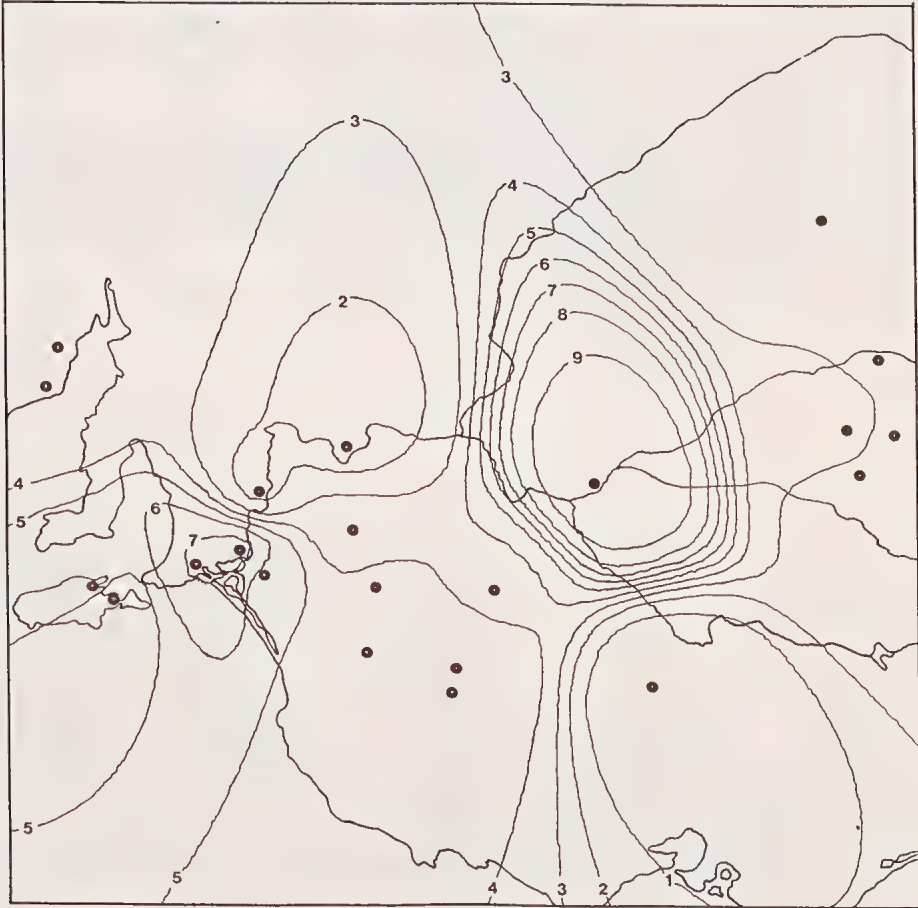


Fig. 21. Contour map (with summary of SNK test) of the lamina length (LL) in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.27; 2 = 0.34; 3 = 0.41; 4 = 0.48; 5 = 0.55; 6 = 0.63; 7 = 0.70; 8 = 0.77; 9 = 0.84.

the length of petiole to length of lamina ratio—LPLL (Fig. 22). Those populations with leaves having the largest ratio (\approx to longest petiole) occur at Balranald (6) and Braendler's (17). As for length of lamina, the Bendigo (7); Overland Corner (14) (with the addition of Walker Flat—15), Cobar (1) and Condobolin (2) populations have the smallest ratio. The other populations (e.g. Goolwa—18, Kingscote—20, Coomandook—16, Kiata—9, American River—19, Bordertown—11, Scorpion Springs—12) have intermediate ratios.



06 17 18 20 16 09 19 11 12 10 08 22 04 13 21 05 02 01 03 14 15 07



Fig. 22. Contour map (with a summary of SNK test) of the petiole length to lamina length ratio (LPLL) in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 4.12; 2 = 4.78; 3 = 5.43; 4 = 6.09; 5 = 6.74; 6 = 7.40; 7 = 8.06; 8 = 8.71; 9 = 9.37.

Both of these characters (LL & LPLL) have high F values (15.81 & 15.68, respectively), while LP (length of pedicel), which shows a similar pattern of variation (Fig. 23), has an F value of 2.47. Therefore, the first two characters account for a more significant amount of the variation.

Another feature, of this most common type, is the frequent significant distinction between the Condobolin (2), West Wyalong (3), Rankin Springs (4), and Barellan (5) populations. Apart from the length of the pedicel—LP (Fig. 23) and the density of hairs on the leaf—LHD (Fig. 24), the density of hairs on the branches (STHD), length of prophylls (LB), length to width ratio of lamina (LLW), and density of glands on the branches (STGD) also distinguish between these populations.

The contour map of the density of hairs of the leaf—LHD (Fig. 24) produces a pattern of variation which is more or less opposite to that of the previous examples (i.e. LL, LPLL, LP). The Cowell (21), Condobolin (2), Overland Corner (14), Walker Flat (15) populations have leaves with high densities of hairs, whereas the Balranald (6) and Goolwa (18) populations have sparsely hairy or glabrous leaves.

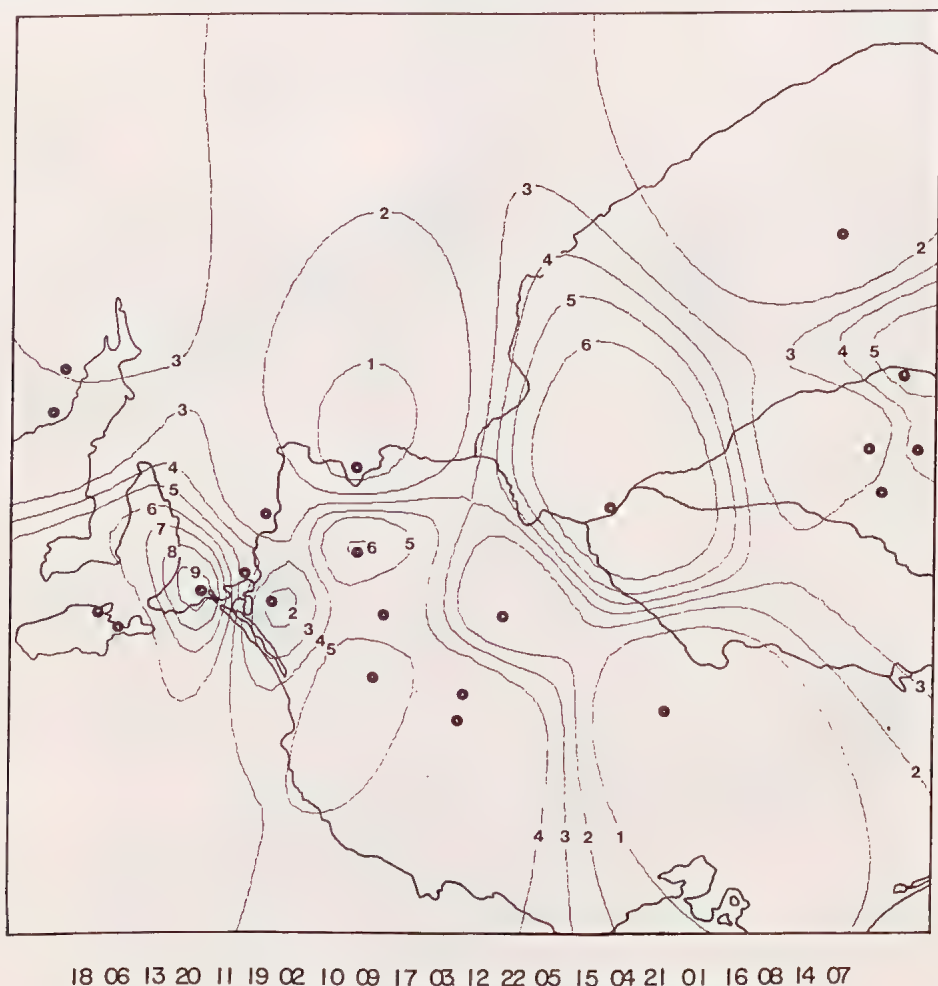


Fig. 23. Contour map (with summary of SNK test) of the pedicel length (LP) in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 6.39; 2 = 6.62; 3 = 6.84; 4 = 7.06; 5 = 7.28; 6 = 7.51; 7 = 7.73; 8 = 7.95; 9 = 8.17.

The ratio of the length of the calyx to that of the calyx tube—KLLT (Fig. 25) produces a different pattern of variation. However, the northern populations and the Bendigo population have low means for this character, similar to the most common pattern. Furthermore, those populations in the south-west of this species distribution still have intermediate to high values, as found in most other characters. The main difference is that the pattern of variation is much simpler and more populations have lower means than usual.

The composite differential formed from the 16 significant characters is presented in figure 26. High contour levels indicate regions of rapid differentiation (change). The most rapid changes occur between the (i) Bendigo (7) and Balranald (6) populations, (ii) Bendigo and Little Desert (10)—Kiata (9) populations, (iii) Little Desert—Kiata and Wyperfeld (8) populations, (iv) Kangaroo Island (19 & 20) and the mainland (18, 21 & 22) populations. There are also regions of change, however to a lesser extent, among the south-western populations (11-18).

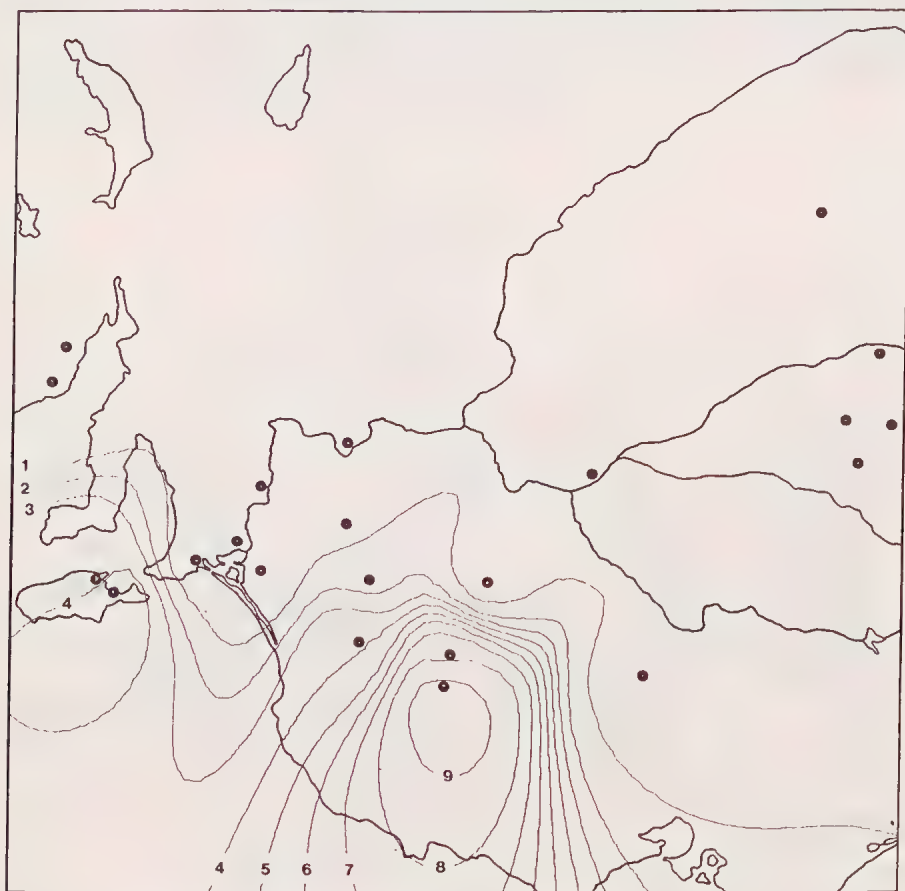


21 02 14 15 13 03 08 10 01 05 17 20 12 04 11 22 07 19 09 16 06 18

Fig. 24. Contour map (with summary of SNK test) of the density of leaf hairs (LHD) in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 2.21; 2 = 2.31; 3 = 2.41; 4 = 2.51; 5 = 2.61; 6 = 2.72; 7 = 2.82; 8 = 2.92; 9 = 3.02.

Although the pattern of geographic variation presented (Fig. 26) is complex, this only represents a simplification of the actual pattern. Therefore, any explanation of this pattern can only be speculative. However, the main features of figure 26 (in conjunction with the univariate surface trend analysis contour maps) suggest at least one explanation for the pattern observed.

The northern populations (1, 14, 21 & 22) are phenetically homogenous and are distinct, collectively, from the more southerly populations (with the exception of the Bendigo population). These populations (with short, more or less sessile leaves, moderately hairy stems, relatively short pedicels, small calyx lobes, and other character states in common) occur in the Arid Moisture region (Gentili 1972), which represents a climatic extremity within the distribution of this species.



10 09 19 11 20 12 04 03 07 13 02 08 17 05 15 14 06 18 01 16 21 22

Fig. 25. Contour map (with summary of SNK test) of the length of the calyx lobes to the length of the calyx tube (KLLT) in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 3.20; 2 = 9.61; 3 = 16.01; 4 = 22.41; 5 = 28.82; 6 = 35.22; 7 = 41.63; 8 = 48.03; 9 = 54.43.

The southern central region of the distribution (populations 9-13, 16-18) is an area of complex differentiation, but to a lesser extent than the four major areas of differentiation discussed before (p. 251). Although a high level of homogeneity exists between the populations of this region, subtle differences do exist, but only on a very local scale. This region (SemiArid Moisture region—Gentilli 1972) appears to be climatically optimal for this species. A similar trend occurs in the Rankin Springs—West Wyalong region (populations 2-4). This latter region, occurring near the SemiArid and SubHumid Moisture regions (Gentilli 1972), is also climatically optimal for this species. The plants in these two regions tend to have larger leaves, frequently with a distinct petiole, longer pedicels, larger calyx lobes, and a number of other characters have similar character states throughout the two regions.

The Bendigo population (7) is relatively distinct (Fig. 26) from the other populations, for example, the leaves are significantly broader and the branches have significantly fewer glands than the northern populations (1, 14, 21, 22). However, a number of character states are very similar to those found in the northern populations (1, 14, 21, 22), for example, short more or less sessile leaves, short prophylls, short pedicels and small calyx lobes.



Fig. 26. The composite differential formed from 16 characters in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.07; 2 = 0.12; 3 = 0.16; 4 = 0.21; 5 = 0.26; 6 = 0.31.

It is hypothesized that the Bendigo population occurs at a climatic extremity, as do the northern populations. Although the Bendigo population occurs near the boundary of the SemiArid and the SubHumid Moisture regions (Gentilli 1972), which in New South Wales represents reasonably good conditions for this species, the slightly higher rainfall and the longer, colder periods during winter may represent a climatic extreme. Since both the Bendigo and northern populations have small narrow leaves, a character (in sect. *Klanderia*) which appears to be easily modified by environmental factors, the climatic regime at Bendigo may be a very real distributional limit. Furthermore, the Bendigo population is relatively isolated by intensive agricultural practices. Therefore, the distinctness of this population will tend to be maintained, since interbreeding with other populations will probably be minimal.

The Kangaroo Island populations (19 & 20) are phenetically distinct from the mainland populations (Fig. 26). These populations have long narrow leaves, moderately large petiole length to lamina length ratios, and moderately long pedicels. Kangaroo Island has been isolated from the mainland for the last 9,300-9,500 years (Lampert 1981). Clearly, the Backstairs Passage and Investigator Strait represent significant barriers to interbreeding.

Morphological variation in *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex

Although the techniques used to study geographic variation were developed to investigate the morphological variation within a species, the same techniques are here applied to an investigation of the morphological variation found within the *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex for this region (Fig. 27). 156 specimens from fourteen populations were analysed (Fig. 27). For further details of the populations refer Table 10.

One common type of pattern of geographic variation is illustrated by the density of hairs on the outer surface of the calyx—KHDO (Fig. 28). The Moonta (4), Cape Borda (5), Kelly Hill Caves (6), and Mt Taylor (7) populations have specimens which have the outer surface of the calyx densely hairy. In this respect, these populations are comparable to the populations of Victoria and New South Wales. While the Cape Cassini (8), Stenhouse Bay (11), Port Lincoln (9), Mt Greenly (10), Venus Bay (13), and Streaky Bay (14) populations have specimens which have glabrous calyces or, at least very sparsely hairy. The remaining populations have a hair density, of the outer surface of the calyx, intermediate between the above extremes. A similar pattern occurs for the density of hairs on the leaves—LHD. In general, this type of pattern (refer, Fig. 28) has high values for the particular character, for Moonta (4) and the south-western Kangaroo Island (5-7) populations, with the lowest values occurring at the coastal populations 8-11, 13 & 14. Populations 1-3, & 12 have values intermediate between the two previous groups.

A slight modification of the previous pattern of geographic variation is illustrated by the position of the hairs on the branches—INTER (Fig. 29). As for the previous pattern, the Moonta (4) and the Kangaroo Island (5-7, and now, also 8) populations have hairs on all 'sides' of the branches. However, low values (\approx glabrous branches) are now restricted to the Stenhouse Bay (11) and Port Lincoln (9) populations. Those populations (1-3, 12) with intermediate values in the previous pattern, plus the Venus Bay (13) and Streaky Bay (14) populations, all have high values in this pattern. A similar trend, with some further subtle modifications, is found for the length of the anther appendage (AAL).

A third pattern of variation is exemplified by the lamina length—LL (Fig. 30), prophyll length (BL), and calyx length (KL). The mainland (9-11, 13 & 14) populations (with the exception of Arno Bay—2) have significantly high values. For example, these populations have long leaves (Fig. 30), long prophylls and large calyces. The Kangaroo Island

populations (5-8) and the other mainland populations have significantly low values. Hence, in the example illustrated in figure 30, these populations have short leaves.

The contour map of the pedicel length—PL (Fig. 31) produces a fourth major pattern of geographic variation which emphasizes the distinctness of the Mt Greenly (10) population. Frequently, the Port Lincoln (9) population is not significantly different from the Mt Greenly population (refer SNK results, Fig. 31). A similar pattern occurs for the lamina length to lamina width (LLW), and for the density of gland on the calyx (KGDO).

Although the above five patterns of variation are the most common, a number of other patterns are found. However, the characters with high *F* values show patterns of one of these five main types.

The composite differential formed from the 18 characters which showed both a significant *F*-test and a significant SNK test (both at the 0.01 level) is presented in figure 32. The most rapid changes occur between the (i) Kangaroo Island (5-8) and the mainland populations, (ii) Stenhouse Bay (11) and Moonta (4) populations, (iii) Stenhouse Bay and Eyre Peninsula (1-3, 9 & 10, 12-14) populations, whereas within Eyre Peninsula, the following populations show high levels of distinctness, (iv) Port Lincoln (9), (v) Mt Greenly (10), and (vi) Venus Bay and Streaky Bay collectively (13 & 14, respectively).

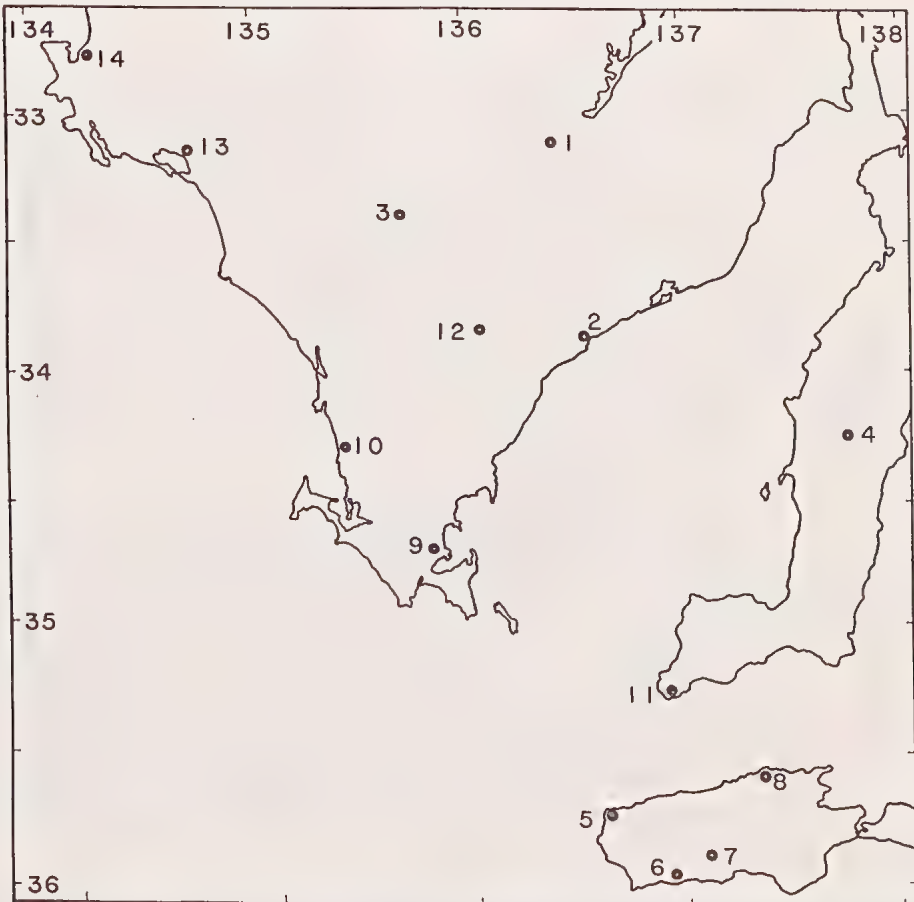


Fig. 27. Locality details of the 14 populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex used for morphological variation studies. For further details of populations refer Table 10.

Table 10. Details of the 14 populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex used for morphological variation studies.

Population	Number of specimens/population
SOUTH AUSTRALIA	
1. Kimba	14
2. Arno Bay	12
3. Lock	5
4. Moonta	10
5. Cape Borda	21
6. Kelly Hill Cave	15
7. Mt Taylor	7
8. Cape Cassini	5
9. Port Lincoln	7
10. Mt Greenly	3
11. Stenhouse Bay	36
12. Hincks Conservation Park	15
13. Venus Bay	3
14. Streaky Bay	3

The more northerly populations (1-4, 12) (excluding 13 & 14) are more or less strongly differentiated from the other more southerly populations. The Kimba (1), Arno Bay (2) and Moonta (4) populations are collectively very homogeneous. The plants of these three localities have short leaves which are relatively broad, short pedicels and short calyces. In general, the density of hairs on the vegetative parts, pedicels and calyces is significantly greater than the density of glands for these same parts. With respect to the expression of these characters (character states), there is a parallel between these populations and the northern populations of *P. aspalathoides* (p. 252). Populations from Lock (3) and Hincks (12) are slightly differentiated from the former three populations (1, 2 & 4). The plants from these two localities frequently tend to have character states which are intermediate between the former three populations (1, 2 & 4) and the four coastal populations (9, 10, 13, & 14) (Figs 28 & 30). Overall, this is an area of phenetic heterogeneity, with some characters having character states similar to populations 1 and 2, whereas other characters having character states similar to some or all of the southern and western coastal populations (9, 10, 13 & 14).

There are strong coastal environmental factors operating on the mainland populations of 9-11, 13 & 14. A 'ridge' of strong differentiation separates populations 4 from 11, and 3 and 12 from 9, 10, 13 & 14 (Fig. 32). All of these populations (9, 10, 13 & 14) tend to be more glandular than the inland populations, except for the Venus Bay and Streaky Bay (13 & 14) populations which are very hairy. These coastal populations also have larger, shiny leaves which are often thickened, longer prophylls, longer pedicels (except populations 13 & 14), and larger calyces than the island specimens. These features are typical of many coastal species, e.g. *Ixodia achillaeoides* (Compositae) (Copley 1982), *Euphrasia collina* ssp. *tetragona* (Scrophulariaceae) (Barker 1982). Other examples and further details are given in Specht (1972; and literature cited therein). It is proposed that the phenotype of these coastal plants is significantly affected by environmental factors. The constitution of the genotype is not known, as my attempts to transplant specimens from these areas were unsuccessful. However, *P. calycina* has been cultivated (refer p. 240) and it maintained its distinctness.

Three major regions of differentiation occur between the five coastal populations under consideration. The two western populations (13 & 14) which represent *P. calycina* [for numerical analysis of this species refer pp. 239-242] are distinct from the other populations

(Fig. 32). The specimens from all the other populations belong to *P. serpyllifolia*. The Mt Greenly (10) population is characterized by specimens with long pedicels. This is further discussed under *P. serpyllifolia* (p. 295). The distinctness of population 9 (Fig. 32) is almost certainly largely an environmentally induced effect. Furthermore, when additional collections (not used in the production of the composite differential) are considered, this population is very heterogeneous and tends to intergrade with population 12. The Stenhouse Bay population (11) is made up of individuals which are glabrous or very sparsely hairy. These specimens have a very high glandular density on most organs. The taxonomic importance of the Mt Greenly form and the Stenhouse Bay form is not known. It seems unlikely that examination of normal macromorphological characters will resolve this part of the *P. serpyllifolia*-*P. microphylla* complex.

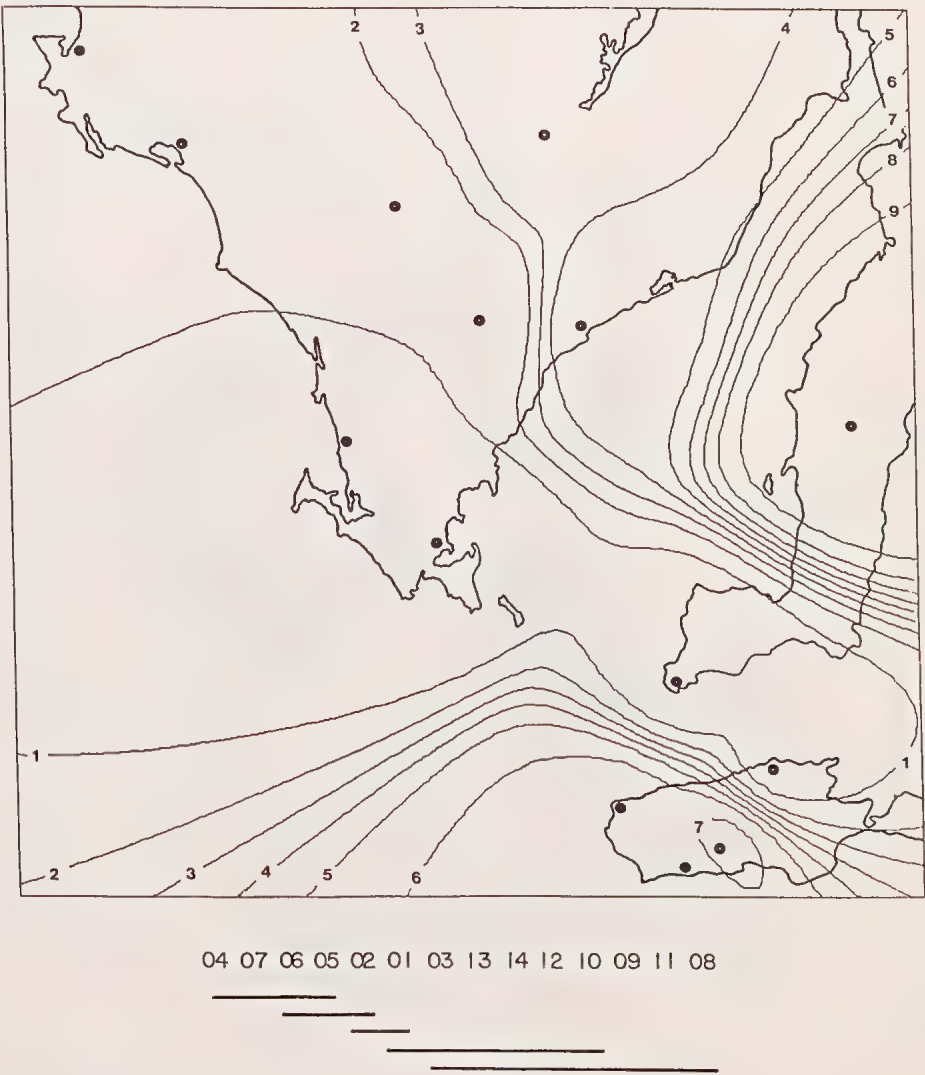


Fig. 28. Contour map (with summary of SNK test) of the density of hairs on the outer surface of the calyx (KHDO) for populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. Contour symbols and values are: 1 = 2.63; 2 = 7.68; 3 = 12.73; 4 = 17.78; 5 = 22.83; 6 = 27.88; 7 = 32.93; 8 = 37.98; 9 = 43.03.

The Investigator Strait and St Vincents Gulf represent significant barriers to interbreeding between the Kangaroo Island (5-8) and mainland populations (Fig. 23) (*cf. P. aspalathoides*, p. 254). The Kangaroo Island populations differentiate into two main groups. One group, which is represented by the Cape Borda (5), Kelly Hill Caves (6) and Mt Taylor (7) populations, is generally very hairy with many irregularly branched hairs. These three populations occur in sandy to sandy loam soils associated with limestone.

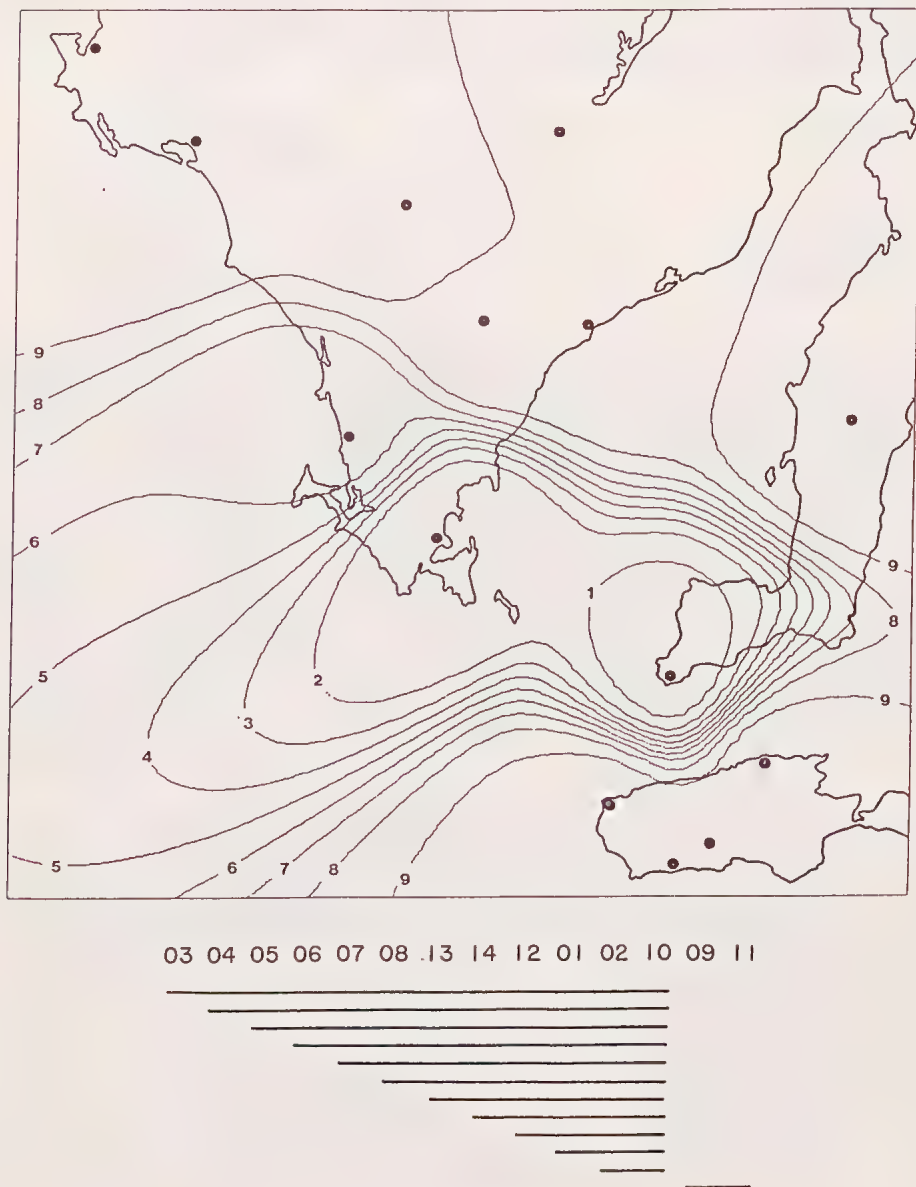


Fig. 29. Contour map (with summary of SNK test) of the position of hairs on the branches (INTER) for populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. Contour symbols and values are: 1 = 1.14; 2 = 1.24; 3 = 1.34; 4 = 1.44; 5 = 1.54; 6 = 1.64; 7 = 1.75; 8 = 1.85; 9 = 1.95.

The habitat of these populations is a *Eucalyptus* dominated mallee community with a more or less dense understorey of shrubs and herbs. The Cape Cassini (8) population, which represents the second group, is associated with skeletal soils of exposed coastal limestone cliffs. These plants are more or less prostrate and are salt-pruned. Most characters for the plants at Cape Cassini show slight (although generally insignificant) differences when compared with populations 5-7. However, in general, the plants are glabrous on most organs, or at least, usually less hairy (with the occasional exception of branches) than the plants of populations 5, 6 and 7. In contrast to these latter populations, the plants from Cape Cassini have only simple hairs, similar to those found throughout most of section *Klanderia*. The taxonomic significance of the irregularly branched hairs, as found in the plants of populations 5-7 (and *P. chlorantha*), is not known.

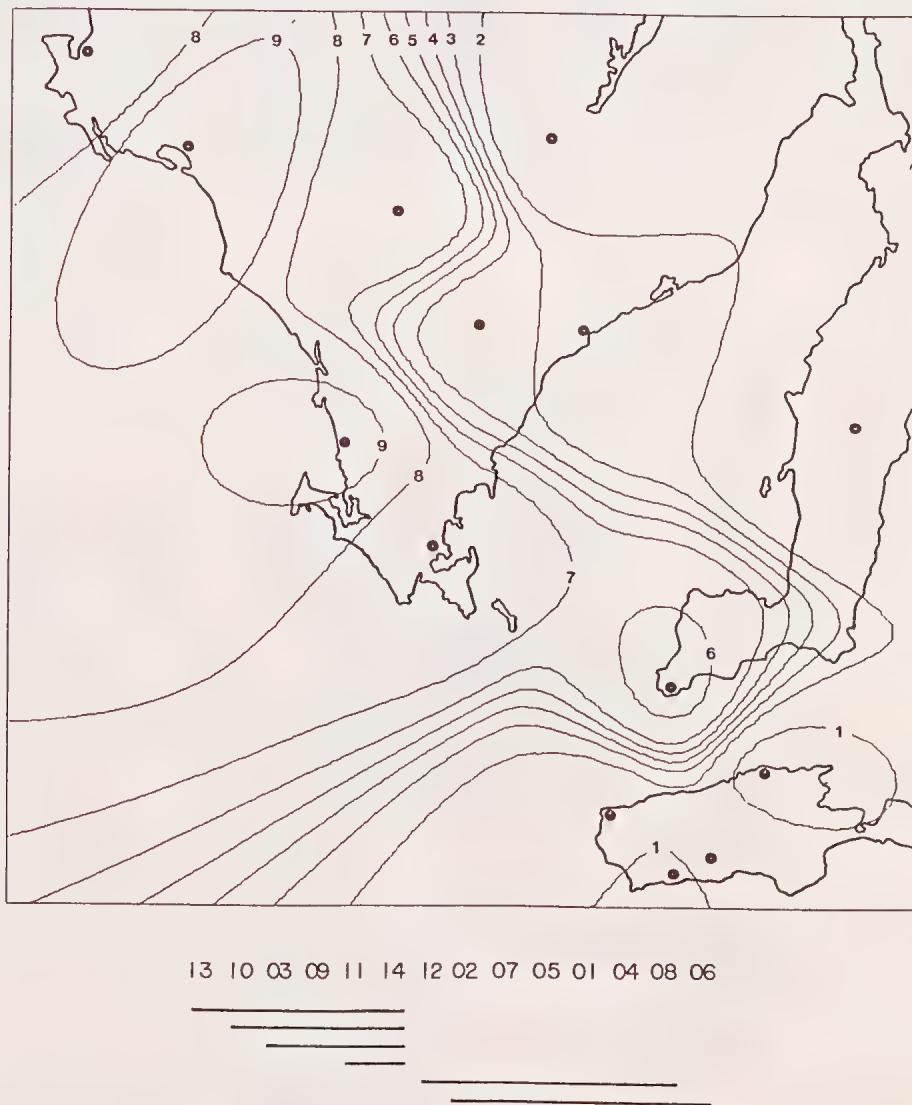


Fig. 30. Contour map (with summary of SNK test) of the lamina length (LL) for populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. Contour symbols and values are: 1 = 1.93; 2 = 2.39; 3 = 2.85; 4 = 3.31; 5 = 3.77; 6 = 4.23; 7 = 4.69; 8 = 5.14; 9 = 5.60.

P. calycina and *P. serpyllifolia* (incl. *P. microphylla*) occur in soils derived from, or at least associated with calcarenites, with the exception of the Mt Greenly population (and some specimens from Port Lincoln, p. 295, which were not included in the composite differential) which occurs in association with quartzites and granitic gneisses. The phenotype of the Mt Greenly and Kirton Point (Port Lincoln) populations of *P. serpyllifolia* may have been induced (at least in part) by the relatively unique geological nature of these areas. Whether there is a corresponding genetic distinctness is not known.

In New South Wales, Victoria, most of Western Australia, and the Murray Mallee region of South Australia, *P. serpyllifolia* is confined to the SemiArid Moisture region (Gentili 1972), with phytohydroxeric indices between 5 and 10. In the area dealt with by this study of the pattern of geographic variation (Fig. 27), SubHumid (SH), SemiArid (SA) and Arid (A) Moisture regions occur, with phytohydroxeric indices ranging from approximately 3 to greater than 10. In figure 33, the average annual rainfall (adapted

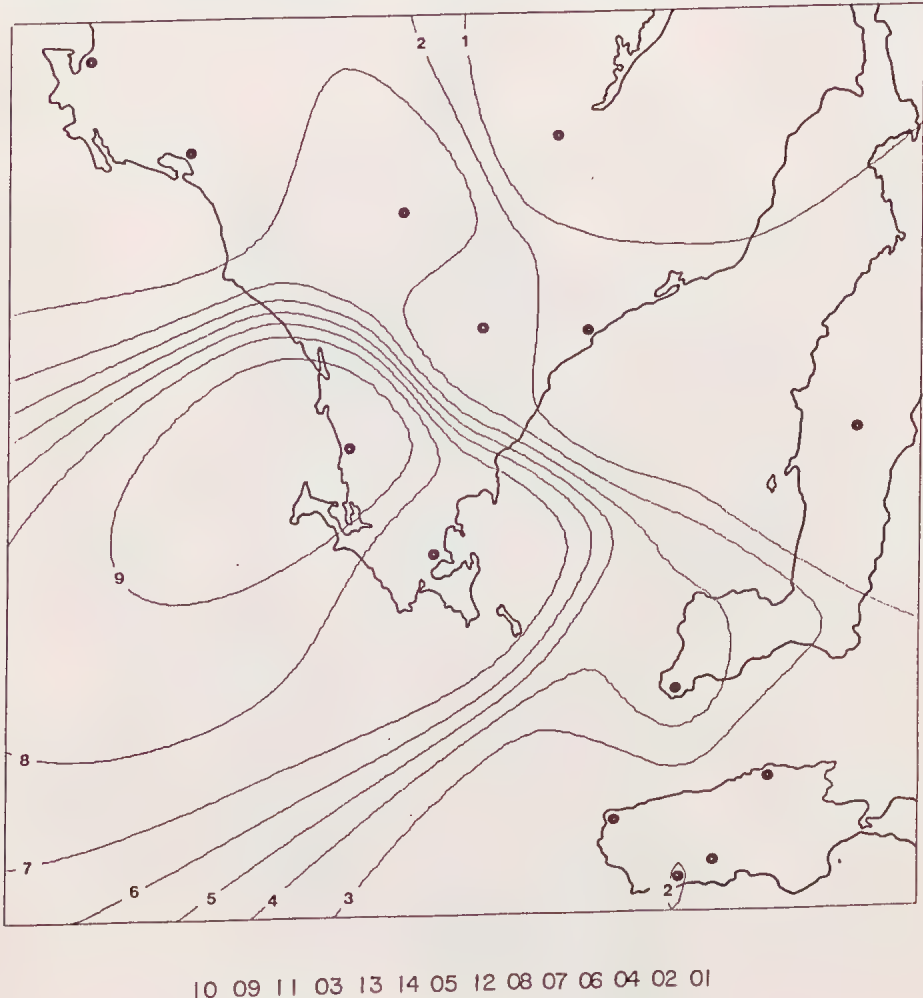


Fig. 31. Contour map (with summary of SNK test) of the pedicel length (LP) for populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. Contour symbols and values are: 1 = 1.78; 2 = 2.75; 3 = 3.73; 4 = 4.70; 5 = 5.68; 6 = 6.66; 7 = 7.64; 8 = 8.62; 9 = 9.59.

from Laut *et al.* 1977b, 1977c), annual phytohydroxeric indices and moisture regions (Gentilli 1972), have been overlaid on the contour map (from differential systematics) for *P. calycina* and *P. serpyllifolia* (cf. Fig. 32).

In this region of South Australia, the coastline is deeply indented by elongated gulfs and peninsulas. This alternation of land and water surfaces results in a large number of localized climatic modifications. Although these modifications are too slight to be of regional significance, they represent very important climatic influences for the local biota. The SubHumid Moisture region (phytohydroxeric indices ≥ 10) discontinuously occurs on the western parts of Kangaroo Island, the most southerly point of Yorke Peninsula (Innes National Park), and the southern parts of Eyre Peninsula (Fig. 33). Populations 5-7, 9 and 11 occur in this region, whereas populations 4, 8 and 10 occur in the SemiArid Moisture region. As well as the Moonta (4) population being morphologically similar to those populations of Victoria and New South Wales, it also occurs in the same climatic zone. Although the Cape Cassini (8) population occurs in the SemiArid Moisture region, the actual level of aridity is probably greater because it occurs on the exposed coastal cliff. The environmental factors operating on population 8 are dramatically different to that operating on the other Kangaroo Island populations (5-7). These climatic differences may explain why the Kangaroo Island populations have differentiated into two main groups.



Fig. 32. The composite differential formed from 18 characters in populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. Contour symbols and values are: 1 = 0.04; 2 = 0.06; 3 = 0.09; 4 = 0.11; 5 = 0.14; 6 = 0.16.

Although Mt Greenly (10) occurs in the SemiArid Moisture region, the local topography associated with its relatively high latitude and proximity to the ocean (hence, increased exposure to the westerly streams of oceanic air), results in this population being under more SubHumid conditions than indicated by the generalized climatic map overlaid in figure 33.

The angle of the western coastline of Eyre Peninsula prevents the rain-bearing winds from penetrating deeply inland (Gentili 1972). Populations 1-3 and 12 occur in the Arid Moisture region (phytohydroxeric indices between 3 and 5). Although the Arno Bay (2) population is more or less coastal, the major climatic influences are from the west. Therefore, the coastal influences only slightly modify the inland arid conditions. Populations 13 and 14 also occur in this moisture region because the rain-bearing winds tend to be tangential to the coastline (the isohyets tending to lie parallel to the west coast, Laut *et al.* 1977c, Fig. 1). Since Venus Bay and Streaky Bay occur at lower latitudes, they are not as strongly influenced by the westerly oceanic air currents as are the more southerly land points. The moisture region in association with the high salt content of the air (in this coastal environment), exposes *P. calycina* to a different set of environmental factors when compared with the other coastal populations of Eyre Peninsula.

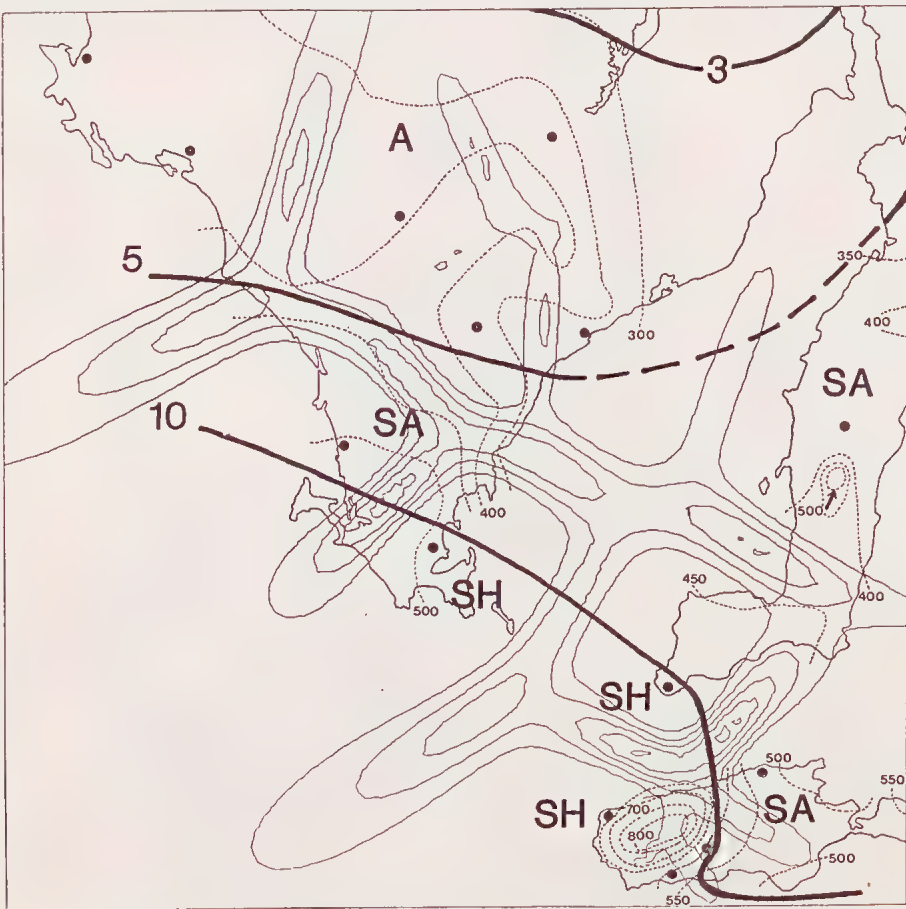


Fig. 33. Annual rainfall distribution (mm) (fine dotted lines), Moisture regions (bold capital letters) and phytohydroxeric indices (bold numbers and lines) overlaid onto the composite differential formed from 18 characters in the populations of the *P. calycina*—*P. microphylla*—*P. serpyllifolia* complex. For contour symbols and values refer Fig. 32. For explanation of symbols used for moisture regions refer text, pp. 260, 261.

Morphological variation in the *Prostanthera laricoides* complex

The Western Australian specimens included in this numerical study of section *Klanderia* (excluding *P. serpyllifolia* ssp. *microphylla*), which are regarded as distinct from the taxa of South Australia and the eastern States (Figs 6 & 8), were studied in more detail. Previously they were regarded as *P. aspalathoides* (populations 1-7 or *P. microphylla* (8) (Fig. 34). The details of the eight populations (based solely on herbarium collections), including the number of specimens in each population, are given in Table 11 and figure 34. For the taxonomic conclusions from the numerical analyses refer pages 243-245.

Of the original 23 characters, 22 showed both a significant *F*-test and a significant SNK test (both at the 0.01 level). Characters STBB, STHL, STHW and STMX (refer Table 1) were deleted from the character set because some individuals had glabrous branches. The remaining 19 characters were used in the analysis of the pattern of geographic variation for these taxa.

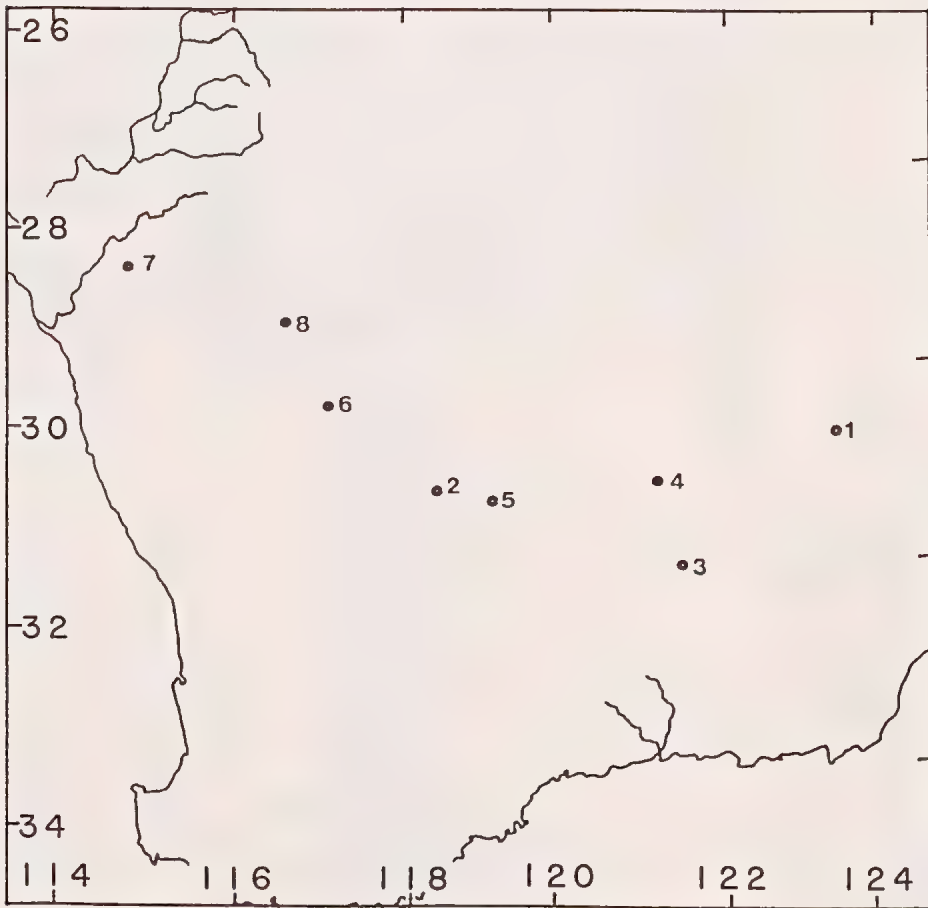


Fig. 34. Locality details of the 8 populations of the *P. laricoides* complex used for morphological variation studies. 1 = Cundeelee; 2 = Campion; 3 = Lake Cowan; 4 = Kalgoorlie; 5 = Southern Cross; 6 = Mt Churchman; 7 = Pindar; 8 = Paynes Find. For further details of populations refer Table 11.

Table 11. Details of the 8 populations of the *P. laricoides* complex used for morphological variation studies.

Approximate locality of Population	Number of specimens/Population
WESTERN AUSTRALIA	
1. Cundelee	5
2. Campion	6
3. Lake Cowan	5
4. Kalgoorlie	6
5. Southern Cross	5
6. Mt Churchman	5
7. Pindar	7
8. Paynes Find	5

Considering each character separately, there are four main pattern types. One common type of pattern of geographic variation is illustrated by the length of the anther appendage—AAL (Fig. 35). Populations 1 (*P. laricoides*) and 8 (*P. patens*) have specimens which have long appendages on the anthers, whereas the other populations have short appendages or the appendages are absent. Slightly more structure to the pattern of variation is found in the contour map of the position of the hairs on the branches—INTER (Fig. 36). *P. patens* (8) has hairs on all 'sides' of the axes, whereas *P. laricoides* (1) and *P. incurvata* (3 & 4) have hairs on two 'sides'. Populations 5 & 6 (*P. semiteres* p.p.) and *P. pedicellata* (7) have glabrous or very sparsely hairy axes. The density of hairs on the branches (STHD), the position of the prophylls (LKLP), and the density of hairs on the outer surface of the calyx (KHDO) all show patterns of variation comparable to this common type. In general, populations 1 (*P. laricoides*) and 8 (*P. patens*) have significantly high values for the respective character, whereas the other populations (2-7) have significantly low values.

Table 12. Details of the 44 collections used in the study of morphological variation in the *P. laricoides* complex.

1. Royce 5472	23. Wilson 3508
2. Royce 5371	24. Wilson 3515
3. Boswell F66	25. Chinnock 3132
4. Butler s.n.	26. Ashby 3585
5. Main s.n.	27. Blackall 3452
6. Beard 4744	28. Rosier 309
7. Canning CBG 26146	29. Rosier 251
8. Phillips CBG 23274	30. Weber 5188
9. Newbey 2538	31. Beard 5944
10. George 2670	32. Demarz 5261
11. Gardner 2060	33. Ashby 2993
12. Blackall 979	34. Ashby 3931
13. Burbidge 2664	35. Ashby 5112
14. Blackall 896	36. Ashby 5035
15. Gardner 2797	37. Maiden s.n.
16. Broadbent 1054	38. Phillips CBS 54467
17. Bale 123	39. Beard 6687
18. Kemsley s.n.	40. Burns 1037/2
19. Phillips CBG 23260	41. Alpin 2551
20. Lidgely 5 & 7	42. Steenbohm s.n.
21. Wilson 3112	43. Ashby 5209
22. Chinnock 3055	44. Ashby 5220

Another common type of pattern of geographic variation is illustrated by the length of the lamina—LL (Fig. 37). *P. laricoides* (1) has long leaves which are significantly different from all other populations. Populations 7 (*P. pedicellata*), 6 (*P. semiteres* ssp. *intricata*)

and 8 (*P. patens*) have very short leaves. The other populations (2-5) have leaves of intermediate length between the two former groups. Other characters which have a similar pattern of variation include, the density of glands on the branches (STGD), the length to width ratio of the lamina (LLW), the density of glands on the outer surface of the calyx (KGDO), and the density of the glands on the lamina (LGD). In general, there is an east-west trend, such that population 1 (*P. laricoides*) has the largest values for the respective character, with populations 3 and 4 (*P. incurvata*), 5, 2 and 6 (*P. semiteres*), 8 (*P. patens*), and 7 (*P. pedicellata*) having progressively lower values.

The third common type is exemplified by the length of the pedicel—LP (Fig. 38). In this type of pattern of variation, there is a general west-east trend. The highest values for the respective character occur in population 7 or 8, with the more easterly populations tending to have progressively lower values. Other characters with a similar pattern of variation are the length of the petiole to the length of the lamina (LPLL), calyx length (KL), and calyx lobe to tube ratio (KLLT).

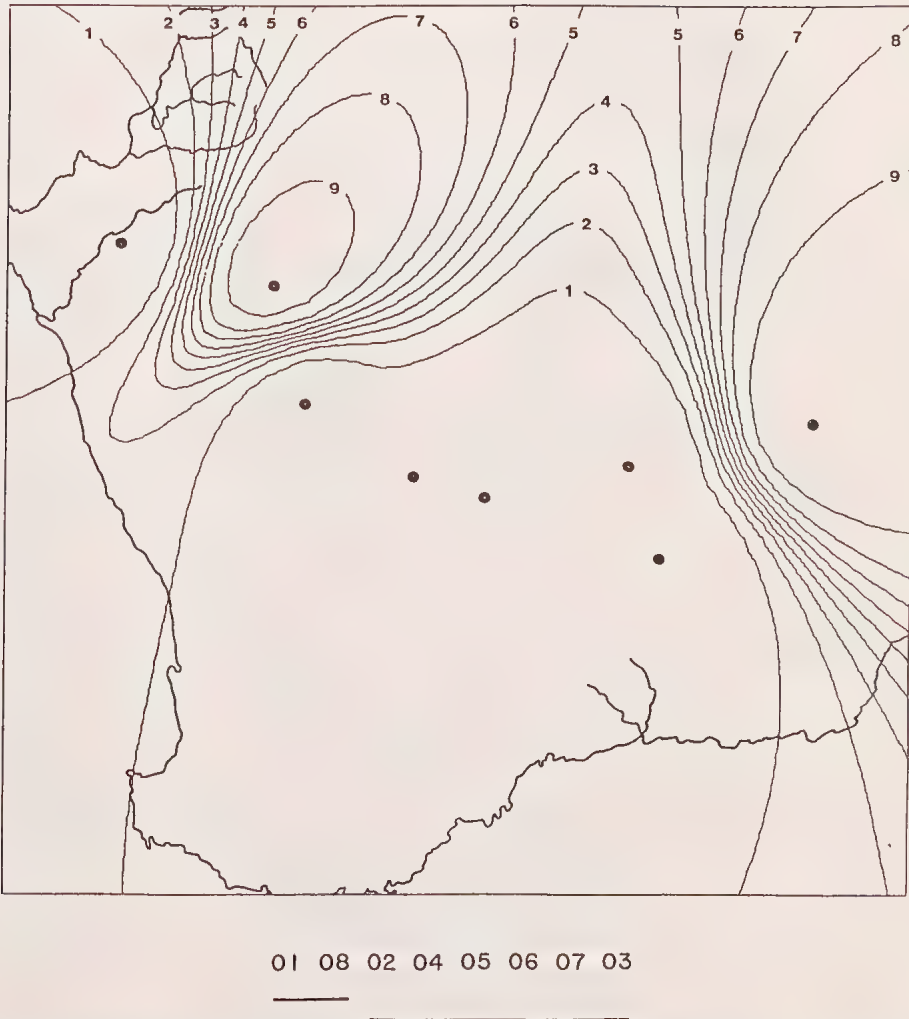


Fig. 35. Contour map (with summary of SNK test) of the anther appendage length (AAL) for populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 0.08; 2 = 0.24; 3 = 0.39; 4 = 0.55; 5 = 0.71; 6 = 0.87; 7 = 1.02; 8 = 1.18; 9 = 1.34.

The final main type of geographic variation occurs for the length of the prophylls—BL (Fig. 39) and the length to width ratio of the prophyll (BLW). This type of pattern of variation is more or less opposite to the first type (refer Fig. 35). Populations 8 (*P. patens*) and 1 (*P. laricoides*) have short prophylls (Fig. 39) and small prophyll length to width ratios, whereas the other populations have long prophylls (Fig. 39) and large prophyll length to width ratios.

The composite differential formed from the 19 characters which showed both a significant *F*-test and a significant SNK test (both at the 0.01 level) is presented in figure 40. The most rapid areas of change occur between (i) *P. laricoides* (1) and *P. incurvata* (3 & 4), (ii) *P. incurvata* and *P. semiteres* (2, 5 & 6), (iii) *P. patens* (8) and all other populations, (iv) *P. pedicellata* (7) and all other populations.

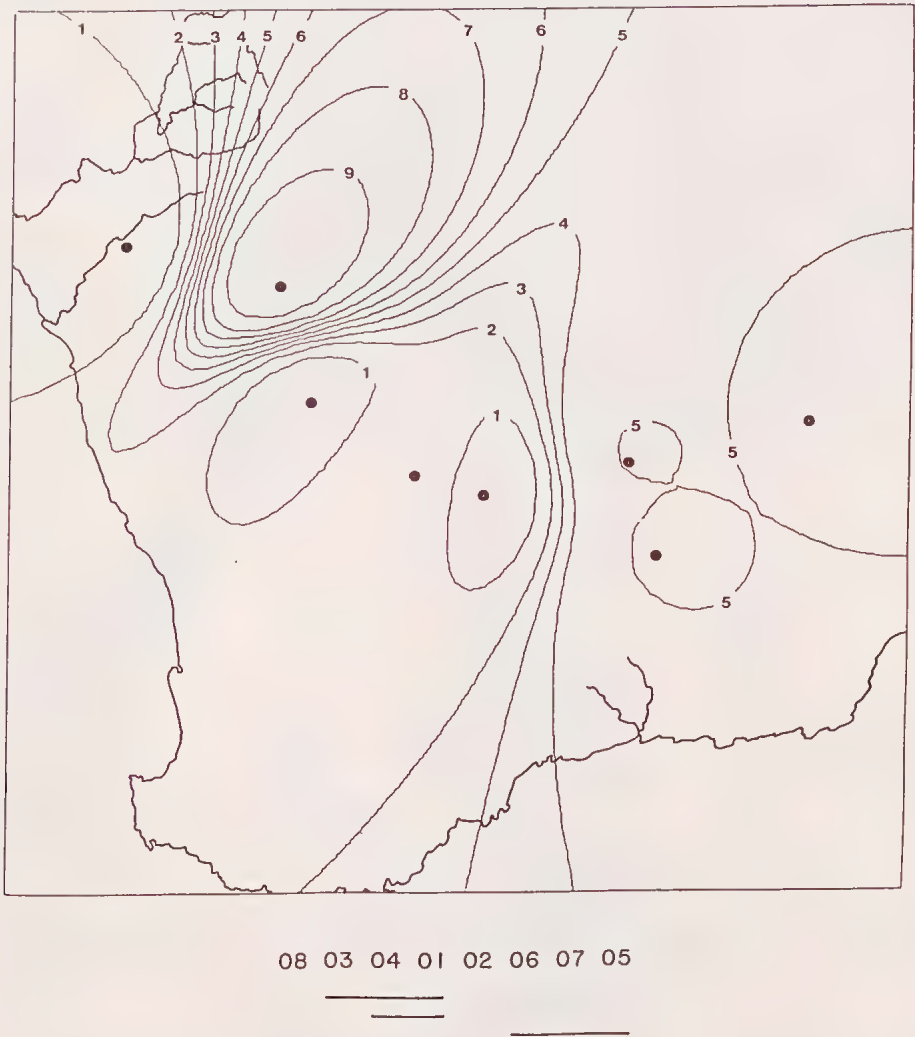


Fig. 36. Contour map (with summary of SNK test) of the position of the hairs on the branches (INTER) for populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 0.11; 2 = 0.33; 3 = 0.55; 4 = 0.77; 5 = 0.99; 6 = 1.21; 7 = 1.43; 8 = 1.65; 9 = 1.87.

The interpretation of the various surface trend analyses and the composite differential is severely limited by the small number of individuals (44) included in this study and by the lack of field information. For example, it is not known if the populations represent interbreeding units. Most populations, as defined by this study, are very heterogeneous (Fig. 17) and additional collections may weaken the distinctness of some populations.

The prostantheras of this region are under-collected, but the present collection localities of the populations may more or less represent their actual distribution. If this is so, the disjunctions assumed here may exist. Based on field-label information (which is very inadequate), Sheets 5 and 10—SW Sheet (Atlas of Australian Soils, Division of Natl Mapping, Dept Natl Development, Canberra, 1968) and Stace *et al.* (1968), all taxa appear to be confined to light soils which are usually sandy to sandy-loam. *P. laricoides* occurs in

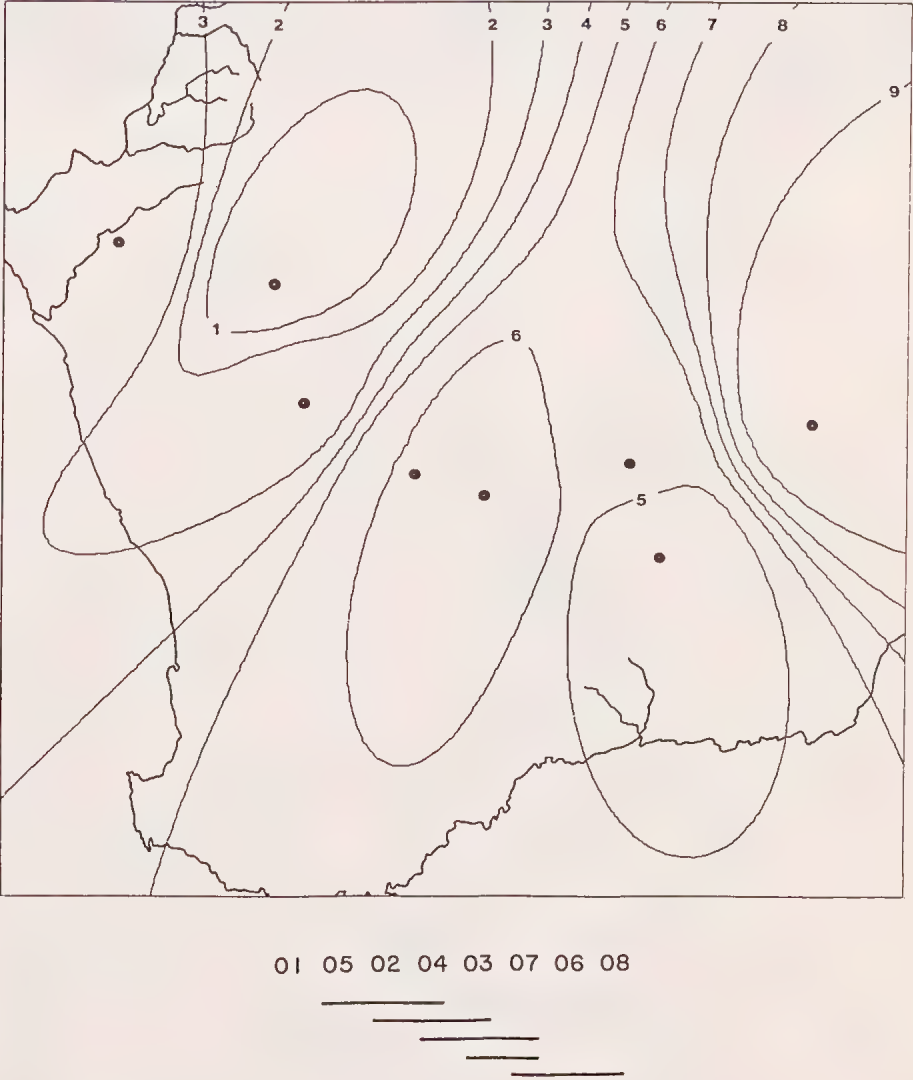


Fig. 37. Contour map (with summary of SNK test) of the lamina length (LL) for populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 2.39; 2 = 3.71; 3 = 5.03; 4 = 6.35; 5 = 7.66; 6 = 8.98; 7 = 10.30; 8 = 11.62; 9 = 12.94.

red sands; *P. incurvata* occurs in shallow calcareous loamy soils (near Kalgoorlie) and in brown calcareous earths (near Lake Cowan); *P. semiteres* ssp. *semiteres* occurs in yellow earths; *P. patens* occurs in shallow earthy loams; and *P. pedicellata* occurs in yellow-brown earths with ironstone gravel on surface. The distribution of soils may represent an important factor controlling the distribution of these taxa. It is of interest to note that *P. pedicellata* and *P. semiteres* spp. *intricata*, which both have long pedicels, occur in yellow to yellow-brown earths.

Without further field information, climatic data does not appear to suggest useful hypotheses to explain the composite differential (Fig. 40). These taxa occur in the Arid Moisture region (Gentilli 1972) (populations 2, 3, 5-8 with phytohydroxic indices between 3 and 5, populations 1 and 4 with phytohydroxic indices between 2 and 3). Although it is tempting to suggest that *P. laricoides* (1) may, at least in part, be distinct because it occurs in a sub-desert (Gentilli 1972) interzone between PerArid and Arid Moisture regions, it is noted that it has been collected from amongst rocks. This taxon may be sufficiently sheltered to avoid the harshness of the subdesert interzone, such that the microclimate may be similar to that of the other populations (2-6).

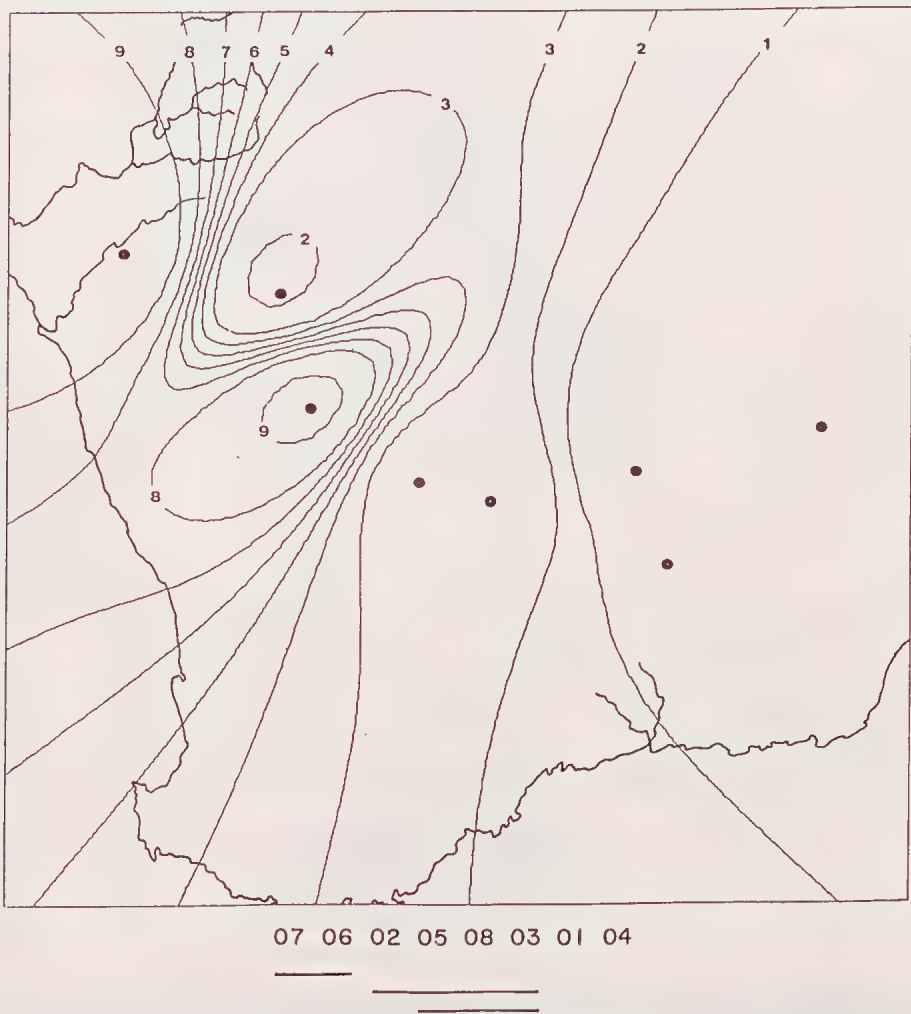


Fig. 38. Contour map (with summary of SNK test) of the pedicel length (PL) for populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 2.79; 2 = 3.31; 3 = 3.83; 4 = 4.35; 5 = 4.87; 6 = 5.39; 7 = 5.91; 8 = 6.43; 9 = 6.95.

Conclusions from geographic variation studies

In the three previously discussed studies I have used geographic variation analysis in two ways. In the study of the *P. aspalathoides* complex I used the various techniques to study the variation within a single species, whereas in the latter two complexes (*P. calycina*-*P. microphylla*-*P. serpyllifolia*, *P. laricoides*) more than one species was involved in each. With respect to my work, the first two aims of geographic variation studies as summarized by Gould & Johnston (1972) have been accomplished. The actual pattern of morphological variation has been established in all three complexes. This has made it possible to suggest and test (subjectively) possible causes for these patterns. Climatic and environmental conditions have been proposed as causal factors influencing the observed morphological variation in *P. aspalathoides*, *P. calycina* and *P. serpyllifolia*. However, there appears to be relatively little climatic and/or environmental differentiation which could explain the morphological variation observed in the *P. laricoides* complex. Detailed field information on this latter complex is required.

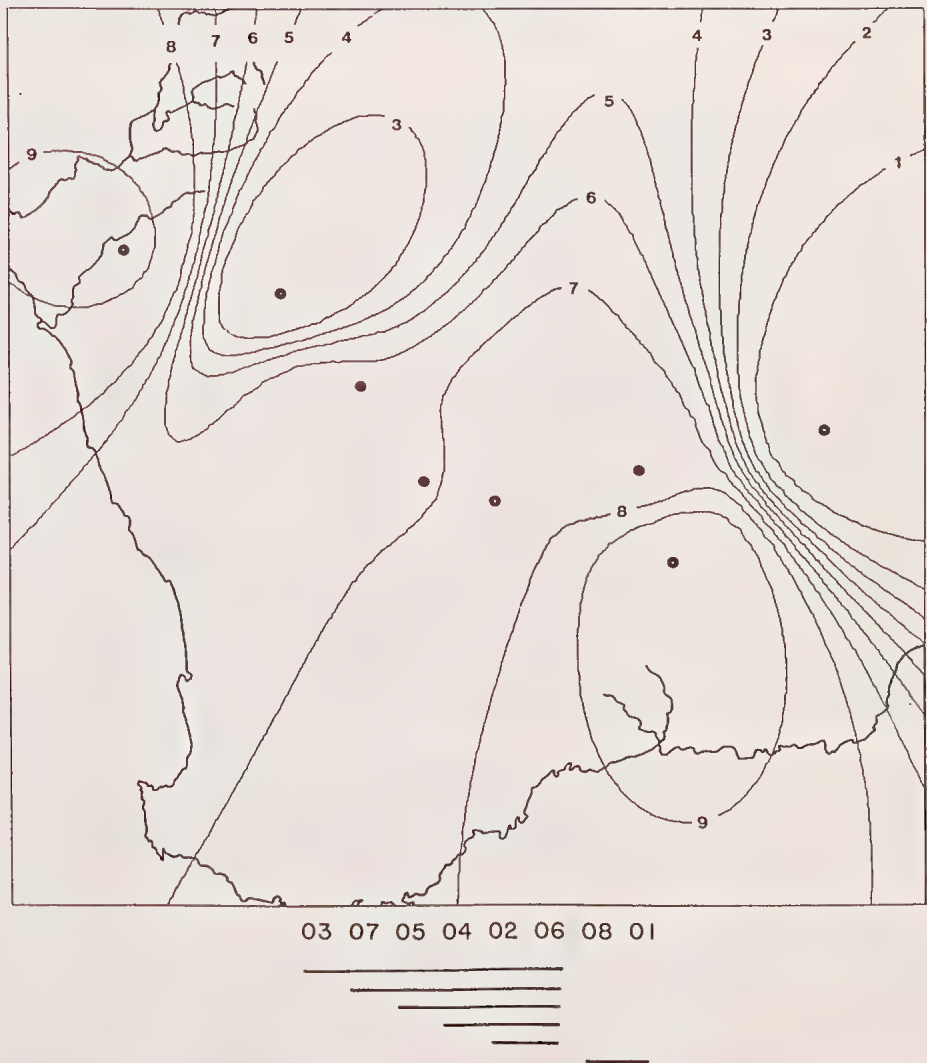


Fig. 39. Contour map (with summary of SNK test) of the prophyll length (BL) for populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 5.11; 2 = 5.36; 3 = 5.62; 4 = 5.88; 5 = 6.13; 6 = 6.39; 7 = 6.64; 8 = 6.90; 9 = 7.16.

Gould and Johnston's (1972) third aim (*viz.* 'to determine if any trends of evolution or speciation are implied by such patterns of variation') is more difficult to accomplish. For instance, one of the main problems is the determination of the evolutionary significance of the morphological differences observed between taxa. This is particularly relevant in this study where character differences are quantitative and so may be of reduced evolutionary significance.

Since the Kangaroo Island populations of both *P. aspalathoides* and *P. serpyllifolia* are relatively distinct from their respective mainland populations, this suggests that these populations may be genetically drifting away from the mainland populations. However, it is not possible to hypothesize on the possible mode of speciation or to provide further insights into the lines of migration of these species because insufficient information was provided by the geographic variation analyses. With respect to the *P. laricoides* complex, no obvious trends of speciation or lines of migration were detected.

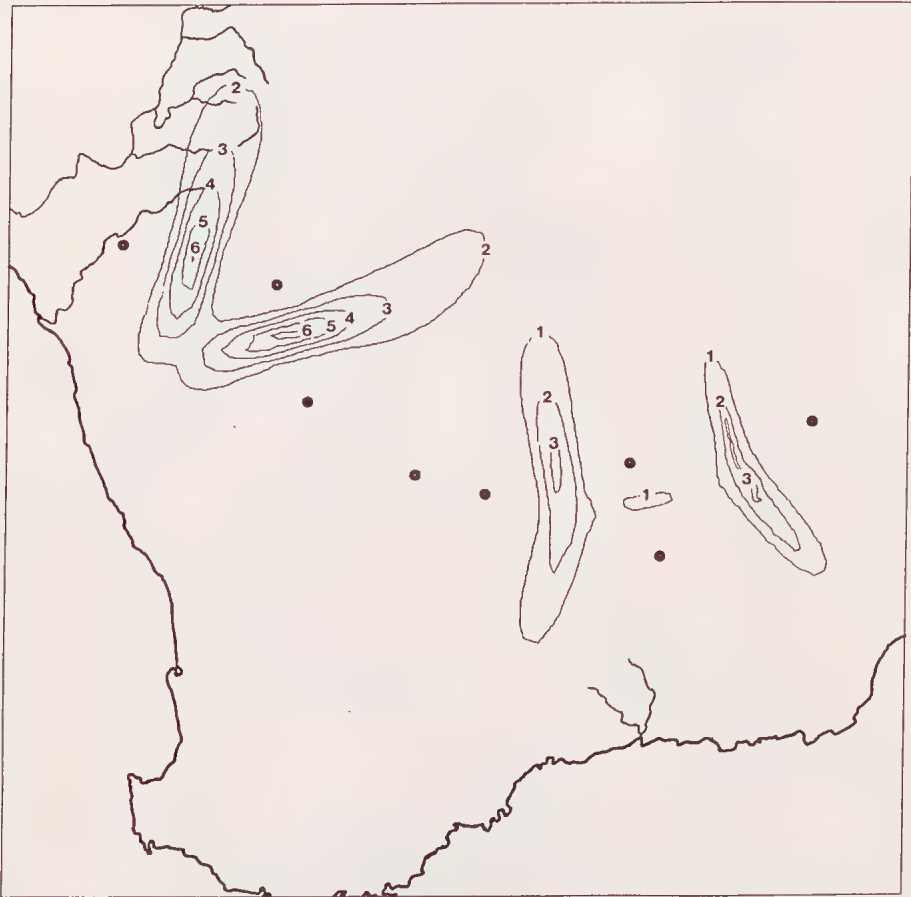


Fig. 40. The composite differential formed from 19 characters in populations of the *P. laricoides* complex. Contour symbols and values are: 1 = 0.04; 2 = 0.10; 3 = 0.16; 4 = 0.22; 5 = 0.27; 6 = 0.33.

Volatile oils (terpenoids)

Volatile oils are valid taxonomic characters (von Rudloff 1975) which have proved useful in the study of specific and infraspecific variation (e.g. Adams 1970b, 1972a; Adams & Turner 1970; Emboden & Lewis 1967; Flake *et al.*, in Runeckles & Mabry 1973; Hefendehl & Murray 1972; Turner 1970; von Rudloff 1967, 1972a, 1973, 1975; Whiffin 1978; Zavarin & Snajberk 1973), and in the detection of hybrids (e.g. Whiffin 1977, 1981; Zavarin *et al.* 1969). They have also proved to be a convenient, accurate and a significant source of data which can be used to characterize individuals or populations. Although there is some subjectivity in the choice of the method of extraction and analysis, the final data are essentially, objectively derived.

The detail of the biosynthesis of volatile oils is relatively unknown, although significant advances have been made by a number of workers (refer Loomis & Croteau, in Runeckles & Mabry 1973). Similarly the mechanism of genetic control of the metabolic processes have not been fully clarified, but in general, the inheritance of most compounds appears to be under the control of one or a few genes (e.g. Irving & Adams, in Runeckles & Mabry 1973).

Materials and methods

Hanover (1966a) and von Rudloff (1972a) have shown that environmental factors have little or no effect on the composition of the volatile oils, but the amount of oil produced may be influenced by such factors. The amount and composition of the oil produced is affected by the maturity of the leaves (Adams & Hagerman 1976; Firmage & Irving 1979; Hanover 1966a; Maarse & Kepner 1970; von Rudloff 1972b; Zavarin *et al.* 1971), and may also be affected by seasonal variation (e.g. Adams 1970a; Attaway *et al.* 1967; Maarse & Kepner 1970; Powell & Adams 1973; von Rudloff 1967, 1972b; Zavarin *et al.* 1971). To minimise such affects, all samples were collected during mid- to late 'spring' (September-early November). Spring is here defined as the season when mature flowers are common throughout the population being sampled. Therefore, collections from Kangaroo Island in November, are regarded as comparable to collections from lower latitudes in September. Adams (1970a), Cheng & von Rudloff (1970), and other workers, recommend that chemosystematic studies should be carried out during autumn and winter because this is the period in which the oil composition is most stable. For various reasons, this was not possible and so great care was taken to ensure that only the previous seasons mature (c. 1 year old) leaves were sampled. To minimize diurnal effects (Adams & Hagerman 1977, Adams 1979) most collections were made between 10 a.m. and 1 p.m.

Fresh foliage samples from each plant were sealed in polyethylene bags, kept as cool as possible until air-freighted to Adelaide, where they were stored at approximately 2°C until processed. Since the samples were kept at low temperatures none were apparently affected by 'sweating' (Penfold & Willis 1961).

Fresh foliage (10-30 g) was steam distilled in an all-glass apparatus (modification of Forss & Holloway 1967). The oil was extracted and concentrated according to Whiffin (1978), except that the oil was extracted into ether instead of freon 11. Oil samples were concentrated with a jet of high-purity nitrogen and stored under that gas in sealed vials at -20°C until analysed.

The oils were analysed on a Perkin Elmer 900 gas-liquid chromatograph, using 15 m x 0.5 mm i.d. FFAP coated stainless steel SCOT columns with He (at 2.5 psi) as carrier gas. Individual runs (with injection size 0.3 µl) were held at 80°C for 3 min., then temperature programmed from 80 to 170°C at 6°/min., and finally held at 170°C for 30 min. Gas flow rates for the flame-ionization detector were: Air 30 psi; H₂ 22 psi. Individual components were identified by their retention times and by co-injection with authentic compounds. A Hewlett Packard 3370A Integrator was used to determine percentage compositions.

Table 13. Mean % composition of selected volatile leaf oils of *P. aspalathoides*.

COMPOUND	Populations					
	1	2	3	4	5	6
1. α - Pinene	tr	0.4	4.3	0.8	2.4	1.4
2. β - Pinene	0.8	2.9	9.98	0.9	4.7	4.2
3. $C_{10}H_{16}$	0.4	0.7	0.48	0.8	2.6	0.4
4. $C_{10}H_{16}$	0	0.7	0.3	0	0	0
5. Limonene	0.7	0.78	3.1	0.4	1.3	0.5
6. 1,8-Cineole	33.5	41.3	45.2	41.1	41.0	29.4
7. ρ - Cymene	2.9	0.9	0.4	1.0	1.1	0.6
8. $C_{10}H_{14}O$	1.0	1.2	0.3	0.1	0.1	0.4
9. $C_{10}H_{18}$	1.4	0.6	0.8	0.1	0.1	0.6
10. Terpinen-4-ol	0.7	0.9	0.5	1.0	1.1	1.2
11. $C_{10}H_{14}O$	0.9	2.1	1.2	0.4	0.1	1.1
12. $C_{10}H_{16}O$	0.9	2.7	0	0.2	0.6	0.3
13. $C_{15}H_{24}$	6.8	4.7	2.7	4.4	3.1	1.4
14. $C_{15}H_{24}$	0.3	0.6	0	0.2	0.1	0.2
15. $C_{10}H_{16}O$	0.7	1.8	0.3	1.0	0.1	0.6
16. α - Terpineol	1.2	3.7	0.7	2.9	0.6	0.4
17. $C_{10}H_{18}O$	3.7	0.4	0.6	1.1	0.1	0.4
18. $C_{15}H_{24}$	1.0	0.7	1.3	0.5	0.5	0.5
19. $C_{10}H_{16}O$	0.4	1.9	1.2	0.6	0.6	3.3
20. $C_{10}H_{14}O$	tr	0.3	0.4	0.4	0.1	0.2
21. Maaliol	34.0	0.2	tr	8.7	1.8	0.3
22. $C_{15}H_{26}O$	3.5	3.5	0.5	4.2	4.6	8.8
23. Globulol	2.1	5.2	4.5	2.2	3.6	6.7
24. Viridiflorol	0.4	0.8	1.0	5.6	11.1	2.2
25. $C_{15}H_{22}O$	0.3	0.1	tr	0.2	0.1	0.3
26. $C_{15}H_{24}O$	0.4	0.4	1.3	1.1	0.1	0.5
27. $C_{15}H_{26}O$	0.3	16.5	tr	0.3	0	0.01

Each individual component of the volatile oils was assigned a unique number by superimposition of the chromatograms and by comparison of retention times. Adams (1972b) regards the errors resulting from miscomparison as only slightly affecting comparisons between taxa. The retention times of α - Terpineol and Limonene, checked after each run, were used as standards. Thirty-seven consistently separable components were obtained. Since it is often difficult to determine whether a compound is present in trace amounts or absent (Southwell 1973), all variation in the data is regarded as quantitative rather than qualitative. Those components which were present in amounts less than 0.1% of the total oil were called 'traces' (refer Table 13) and were given an arbitrary value of 0.1%. Since the biogenesis of unknown compounds can not be known, there is a very real danger that some characters ('peaks') may represent one biogenetical system (Weimarck 1972), whereas others may represent several independent systems. Even though some characters may be highly correlated because they belong to the one biogenetical pathway, they receive equal 'weighting' with other characters in the various numerical analyses. Although I was unable to avoid the effects of the above type of character correlation, because the biogenetic pathways are not known for *Prostanthera*, only those chemical characters whose identity had been verified, at least tentatively (using the previously discussed techniques), were used in subsequent analyses (Table 13). My final volatile leaf-oil character set is based on that used by Lassak (1980).

Numerical analyses of volatile leaf-oils of *Prostanthera aspalathoides*

The volatile leaf oils of forty-four individuals of *P. aspalathoides* were sampled (refer figure 44 for details of specimens). The location of these populations is shown in figure 41, with further details in Table 14.

Table 14. Details of the 44 collections used in the study of the volatile leaf oil variation of *P. aspalathoides*.

Population	Number of specimens/population
SOUTH AUSTRALIA	
1. American River	3
2. Kingscote	22
3. Braendler's Scrub	3
VICTORIA	
4. Little Desert	4
5. Bendigo	5
NEW SOUTH WALES	
6. Rankin Springs	7

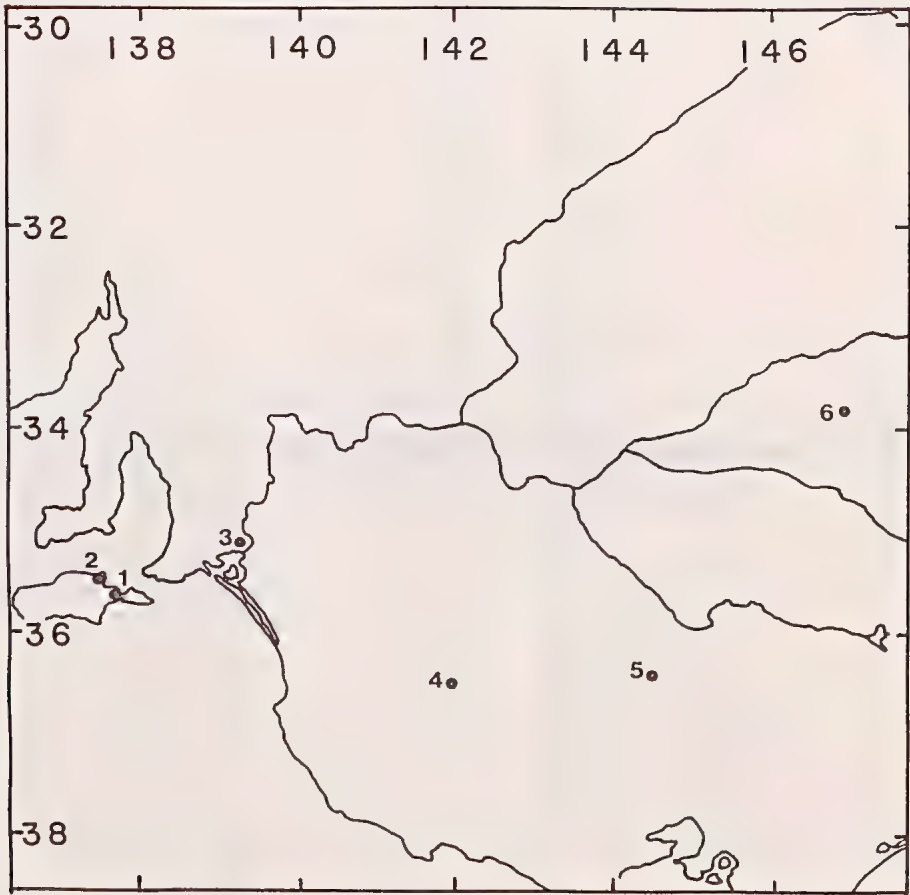


Fig. 41. Locality details of the 6 populations of *P. aspalathoides* used for volatile leaf oil variation studies. 1 = American River; 2 = Kingscote; 3 = Braendler's Scrub; 4 = Little Desert; 5 = Bendigo; 6 = Rankin Springs. For further details of populations refer Table 14.

Evaluation of volatile leaf-oil character set

Most characters (70.4%) were nonparametrically distributed. Kurtosis and skewness values are presented in Table 15. All characters appear to provide a high level of 'uniqueness' with respect to their information content ($-0.60 < \text{Kendall's tau} < +0.60$, Table 16). The first three axes (factors) of principal factor analysis account for 48% of the variance. Those characters with high scores on these three factors are summarized in Table 17. Characters 8, 11-16 and 27 tend to cluster in the plot of factor 1 versus factor 2 (Fig. 42), scoring high on factor 1 (Table 17), but low on all other factors. Characters 1, 2, 4, 5 and 7 loosely cluster in the plot of factor 2 versus factor 3 (Fig. 43), scoring high on factor 2 (Table 17). It can also be seen that characters 9, 13, 17 and 21 have high positive scores (Fig. 43, Table 17).



Fig. 42. Principal factor plot (function 1 versus function 2) of the volatile leaf oils of *P. aspalathoides*. For further details of volatile leaf oils refer Table 15.

Table 15. Kurtosis and skewness values for 27 volatile leaf oil compounds of *P. aspalathoides*.

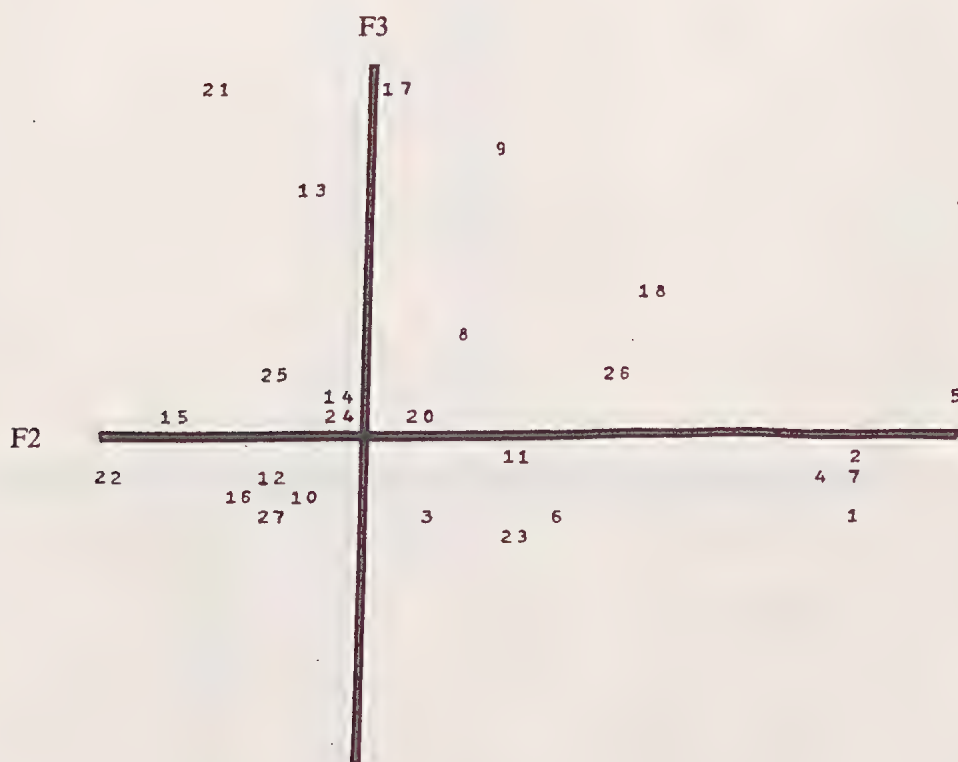
Character	Kurtosis	Skewness
1. α -Pinene	5.45	2.23
2. β -Pinene	9.63	2.67
3. $C_{10}H_{16}$	1.34	1.12
4. $C_{10}H_{16}$	3.74	1.12
5. Limonene	6.64	2.17
6. 1,8-Cineole	-0.85	-0.56
7. p -Cymene	2.07	1.32
8. $C_{10}H_{14}O$	-1.23	-0.10
9. $C_{10}H_{18}$	0.21	0.74
10. Terpinen-4-ol	18.44	3.74
11. $C_{10}H_{14}O$	-0.36	0.14
12. $C_{10}H_{16}O$	-1.33	0.13
13. $C_{15}H_{24}$	-0.05	-0.14
14. $C_{15}H_{24}$	1.54	1.07
15. $C_{10}H_{16}O$	-1.30	-0.04
16. α -Terpineol	-0.45	0.69
17. $C_{10}H_{18}O$	11.04	3.26
18. $C_{15}H_{24}$	5.35	1.81
19. $C_{10}H_{16}O$	33.91	5.58
20. $C_{10}H_{14}O$	-0.18	0.93
21. Maaliol	9.80	3.17
22. $C_{15}H_{26}O$	26.21	4.69
23. Globulol	3.83	1.54
24. Viridiflorol	4.57	2.42
25. $C_{15}H_{22}O$	8.13	2.79
26. $C_{15}H_{24}O$	2.61	1.58
27. $C_{15}H_{26}O$	-1.24	0.67

Table 16. Correlation coefficients for selected character-pairs (Kendall's tau) for volatile leaf oils of *P. aspalathoides*.

Character-pair	Kendall's tau
C1 — C2	0.4907
C2 — C5	0.5751
C2 — C7	0.5061
C4 — C20	0.4910
C8 — C11	0.5064
C8 — C12	0.5623
C8 — C14	0.6018
C8 — C16	0.5204
C8 — C19	0.5198
C11 — C19	0.5117
C12 — C15	0.5761
C12 — C16	0.5954
C12 — C27	0.5922
C15 — C16	0.5484
C16 — C27	0.5586

Table 17. Volatile leaf oil compounds with high factor scores on the first three extracted factors from Principal factor analysis.

Factor 1		Factor 2		Factor 3	
12. $C_{10}H_{16}O$	0.887	18. $C_{14}H_{24}$	0.798	21. Maaliol	0.742
15. $C_{10}H_{16}O$	0.828	2. β -Pinene	0.725	17. $C_{10}H_{18}O$	0.651
27. $C_{15}H_{26}O$	0.768	5. Limonene	0.643	6. 1,8-Cineole	-0.613
8. $C_{10}H_{14}O$	0.744	4. $C_{10}H_{16}$	0.610	9. $C_{10}H_{18}O$	0.575
1. α -Pinene	-0.738	23. Globulol	0.519		
16. α -Terpineol	0.729	26. $C_{15}H_{24}O$	0.511		
11. $C_{10}H_{14}O$	0.629				
14. $C_{15}H_{24}$	0.624				
13. $C_{15}H_{24}$	0.534				
5. Limonene	-0.518				

Fig. 43. Principal factor plot (function 2 versus function 3) of the volatile leaf oils of *P. aspalathoides*. For further details of the volatile leaf oils refer Table 15.

Numerical analyses of specimens

Whiffin (1982b) suggests that volatile oil data sequentially standardized by standard deviation is marginally better than standardization by range. However, since both are useful, the latter procedure was used so as to conform with that used on the morphological data (p. 236). The nearest-neighbour phenogram of 41 individual specimens (based on a matrix of Manhattan metric distances of the full data set) is presented in figure 44. The most striking feature of this phenogram is the within-population heterogeneity. The Kingscote population (2) (*viz.* Conn 1047) has the Little Desert population (4) (*viz.* Conn 697) as its nearest neighbour (Fig. 44), not the American River population (1) as might be expected. However, the American River population has the Kingscote population as its second nearest neighbour. The American River population (*viz.* Conn 1067) has Conn 694 (of the Little Desert population) as its nearest neighbour (Fig. 44). The Rankin Springs population (6) has its closest relationship with the Little Desert population (4), then to Bendigo (5), and finally with Braendler's Scrub (3).

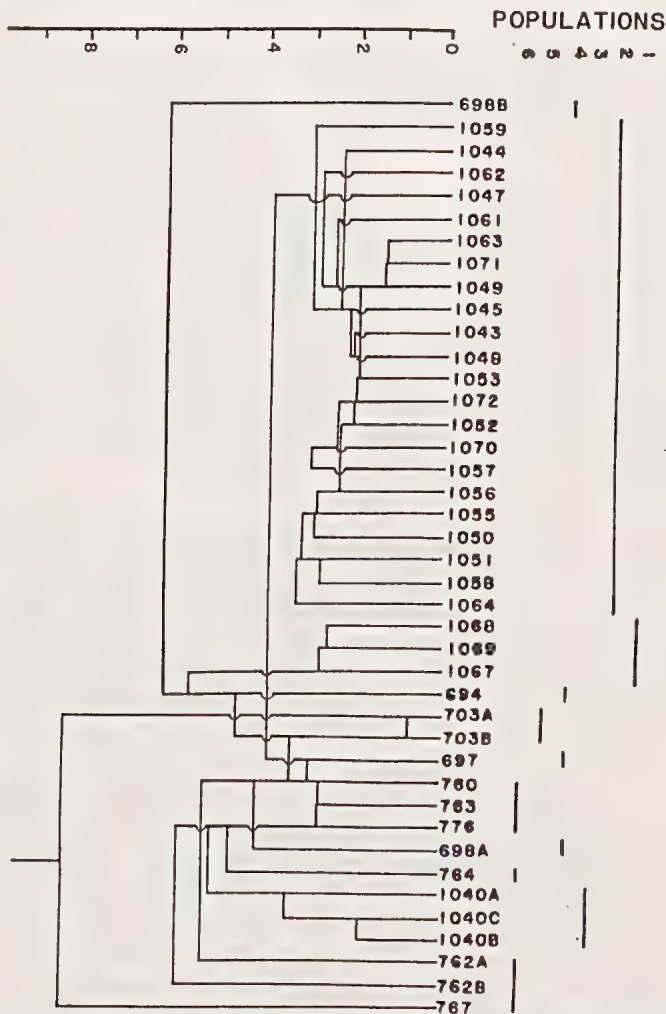


Fig. 44. Nearest neighbour phenogram generated from the Manhattan distance matrix of 41 specimens of *P. aspalathoides* (based on the volatile leaf oils). The collection numbers given immediately above the phenogram were all collected by the author. The horizontal lines beside the phenogram group the specimens into their respective populations (for further details of populations refer Table 14).

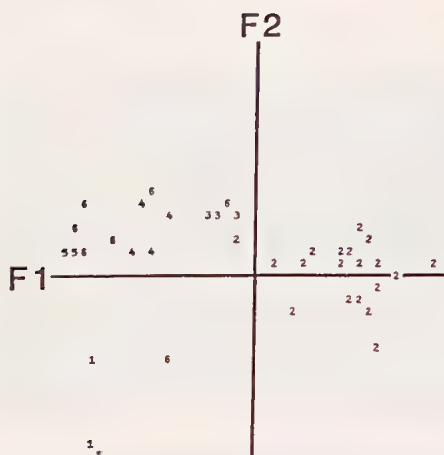


Fig. 45. Principal coordinate plot (function 1 versus function 2) of the *P. aspalathoides* populations (based on volatile leaf oils). 1 = American River; 2 = Kingscote; 3 = Braendler's Scrub; 4 = Little Desert; 5 = Bendigo; 6 = Rankin Springs. For further details of populations refer Fig. 41 and Table 14.

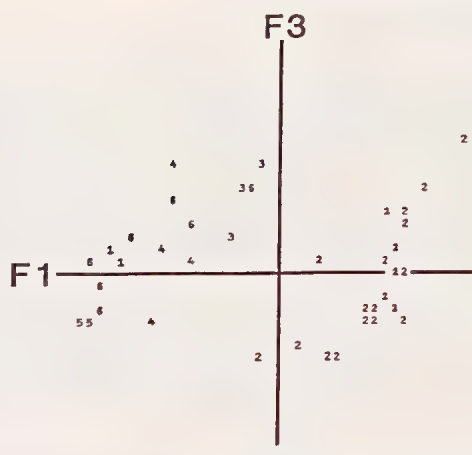


Fig. 46. Principal coordinate plot (function 1 versus function 3) of the *P. aspalathoides* populations (based on volatile leaf oils). 1 = American River; 2 = Kingscote; 3 = Braendler's Scrub; 4 = Little Desert; 5 = Bendigo; 6 = Rankin Springs. For further details of populations refer Fig. 41 and Table 14.

The first four axes of the principal coordinate analysis provide a useful simplification of the data because they account for 68.33% of the total variation. In the plots of function 1 versus function 2 (Fig. 45), and function 1 versus function 3 (Fig. 46), the Kingscote population (2) forms a distinct cluster, separate from all other populations. The American River population (1) is distinct from all populations on several functions (e.g. Fig. 45), but on others (e.g. Fig. 46) it is closely related to the mainland populations. The Rankin Springs population (6) usually forms indistinct clusters. The Bendigo population (5) has its closest relationship with the Rankin Springs population and is usually distinct from the other mainland populations (3 & 4). Overall, the mainland populations are weakly clustered on most functions such that they do not form easily separable population-based clusters.

Geographic variation of *Prostanthera aspalathoides* based on volatile leaf-oils

Of the original 27 characters, 18 showed both a significant *F*-test and a significant SNK test (both at the 0.01 level). Considering each character separately, there are four pattern types. One common type of pattern of geographic variation is illustrated by α - Pinene (character 1) (Fig. 47) and β - Pinene (character 2). The Braendler's Scrub population (3) is rich in α - Pinene and is significantly different with respect to this character, from all other populations. The two Kangaroo Island populations (1 & 2) have the lowest quantities of α - Pinene, whereas the other populations (4-6) have intermediate amounts.

The second common type is exemplified by the character 18 ($C_{15}H_{24}$) (Fig. 48). The Kingscote (2) and the Little Desert (4) populations are rich in this sesquiterpene but the other populations (1, 3, 5 & 6) have progressively lower amounts of this component. The monoterpene $C_{10}H_{14}O$ (character 13) has a similar pattern of geographic variation.

The third common type of pattern is a slight modification of the previous type. This type is illustrated by ρ - Cymene (character 7) (Fig. 49). The Kangaroo Island populations (1 & 2) are rich in ρ - Cymene (the Kingscote population richer). The mainland populations tending to show a combined west-east and north-south trend. That is, the Rankin Springs (6) and the Braendler's Scrub (3) populations are richer in the relevant component (e.g. ρ - Cymene, Fig. 46; character 11 - $C_{10}H_{18}$), with the Little Desert (4) and the Bendigo (5) populations having progressively smaller amounts.

The fourth common type of pattern is exemplified by character 15 - $C_{10}H_{16}O$ (Fig. 50) and Maaliol (character 21). The Kangaroo Island populations (1 & 2) are rich in the relevant component, whereas the Braendler's Scrub (3) population has significantly low amounts. The other populations (4-6) are intermediate between the previous two groups.

The composite differential formed from the 18 characters which showed both a significant *F*-test and a significant SNK test (both at the 0.01 level) is presented in figure 51. The most rapid changes occur between (i) the Kangaroo Island (1 & 2) and mainland (3-6) populations, and (ii) between the Braendler's Scrub (3) and the Victorian (4 & 5) populations.

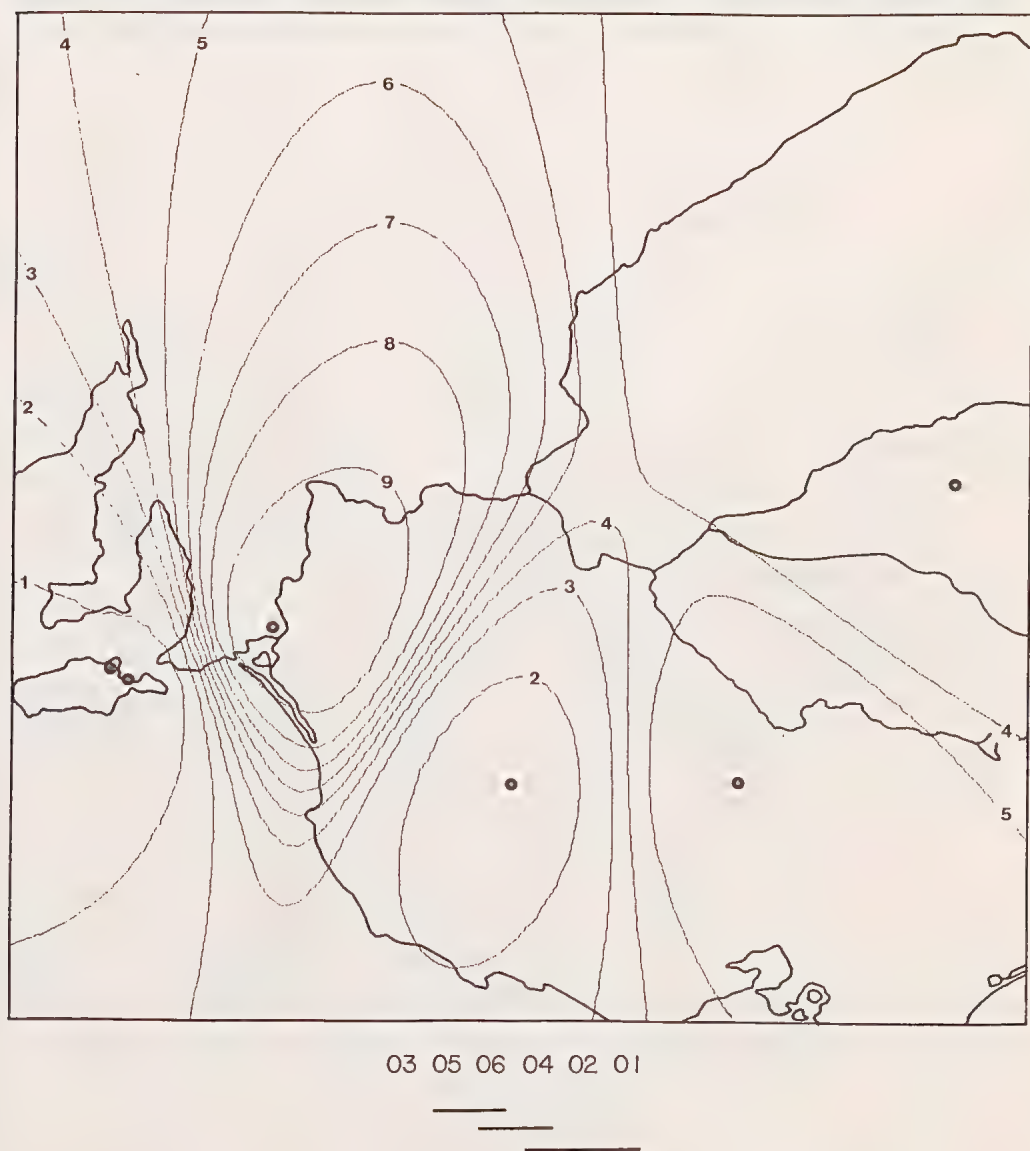


Fig. 47. Contour map (with summary of SNK test) of % composition of α - Pinene (character 1) for populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.33; 2 = 0.80; 3 = 1.27; 4 = 1.74; 5 = 2.21; 6 = 2.68; 7 = 3.15; 8 = 3.62; 9 = 4.09.

Since the sample is very small for most populations (Table 14), interpretation of these results is difficult and by necessity must be tentative. One consequence of limited population sampling is that it is not known how representative these individuals are of the respective populations. Since chemical forms are usually merely quantitatively different (e.g. Hellyer *et al.* 1969), a larger sample improves the statistical basis for any consideration of these differences. Obviously the optimal sample size is dependent upon many factors which are possibly different for different taxa. Adams (1970b, 1972a), Hunt & von Rudloff (1974), and von Rudloff (1972a) have found that populations represented by five individuals can

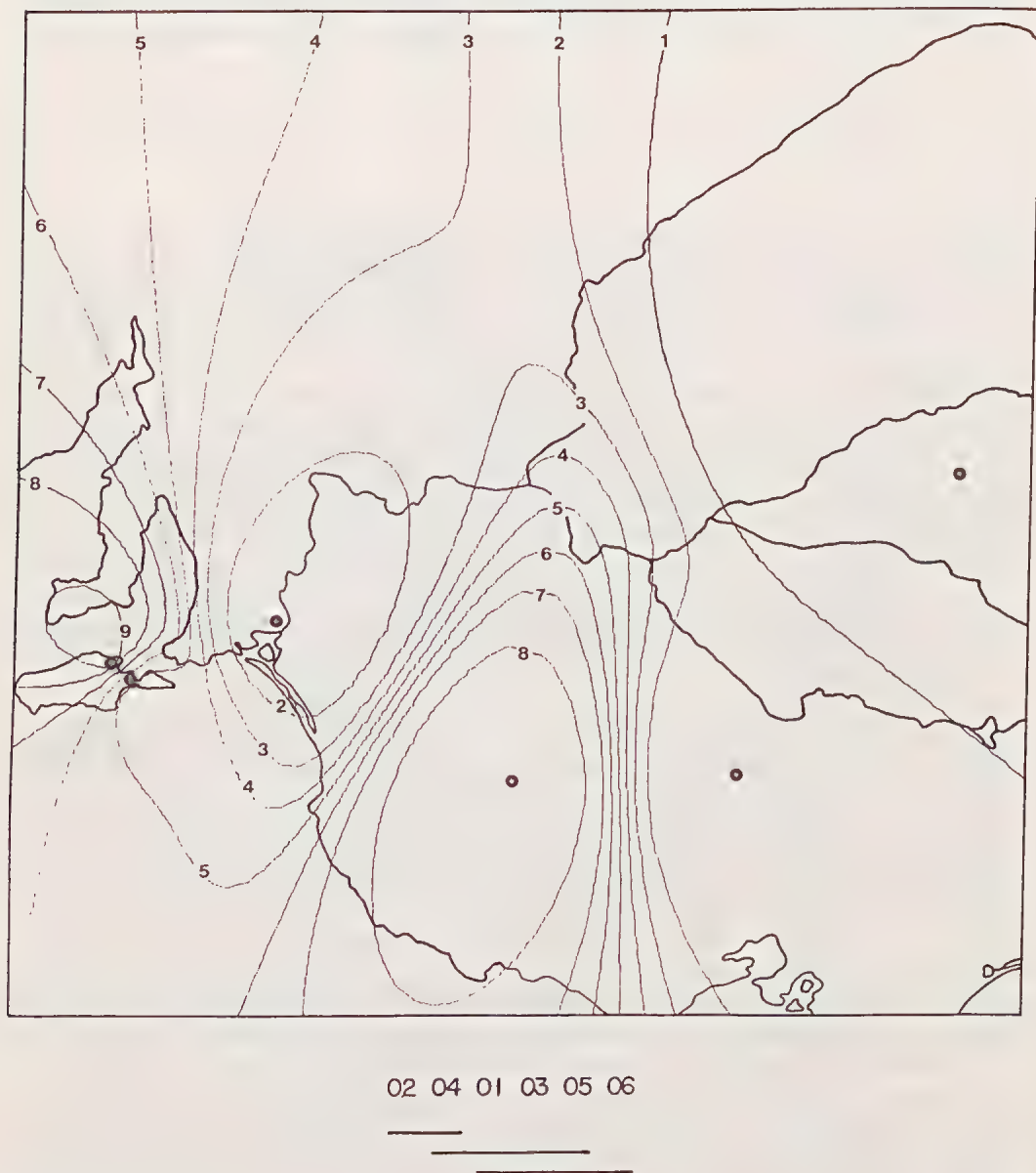


Fig. 48. Contour map (with summary of SNK test) of % composition of $C_{15}H_{24}$ (character 18) for populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.53; 2 = 0.86; 3 = 1.18; 4 = 1.50; 6 = 2.14; 7 = 2.47; 8 = 2.79; 9 = 3.11.

still show significant differences between populations. However, five individuals are more likely to represent the minimal sample size. It can be seen, for example, that five individuals probably could not adequately represent the heterogeneity of the Kingscote population (Fig. 44).

It was found that the amount of 1,8—Cineole was consistently high (mean value of 38.6% of the total composition for all populations) and is the major compound of the leaf oils. Lassak, in Althofer (1978) and Lassak (1980) also found that 1, 8—Cineole was the main component of *P. aspalathoides*. Similarly, in a preliminary study of *P. serpyllifolia* (the Mt Greenly population), I found that it was also the main component (54.4%).

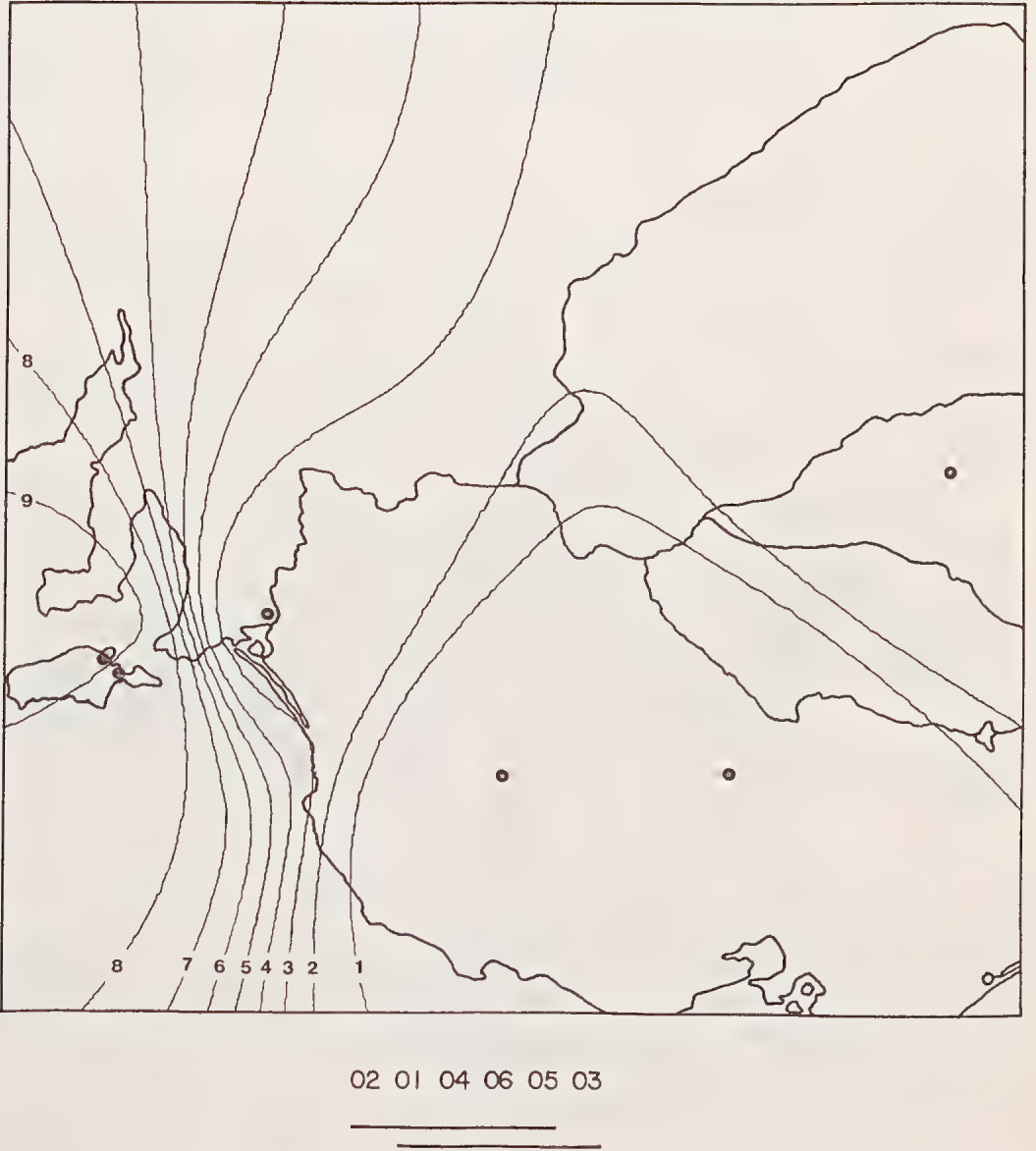


Fig. 49. Contour map (with summary of the SNK test) of % composition of *p*—Cymene (character 7) for populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.16; 2 = 0.28; 3 = 0.39; 4 = 0.51; 5 = 0.63; 6 = 0.75; 7 = 0.86; 8 = 0.98; 9 = 1.10.

The Kangaroo Island populations (1 & 2) have significantly high values of ρ -Cymene and several other monoterpenes (e.g. characters 9, 13 & 15). These populations are also rich in the two sesquiterpenes, Maaliol and character 18 (Table 13). The presence of Maaliol and ρ -Cymene is of particular interest since the specimens (from New South Wales) processed by Lassak (1980) lacked both of these compounds.

The Braendler's Scrub population (3) is characterized by significantly high values of α - and β -Pinene. However, this may be an artifact of inadequate sampling, particularly for α -Pinene, which had values ranging from 2.3 to 5.9%. Since Lassak (1980) recorded

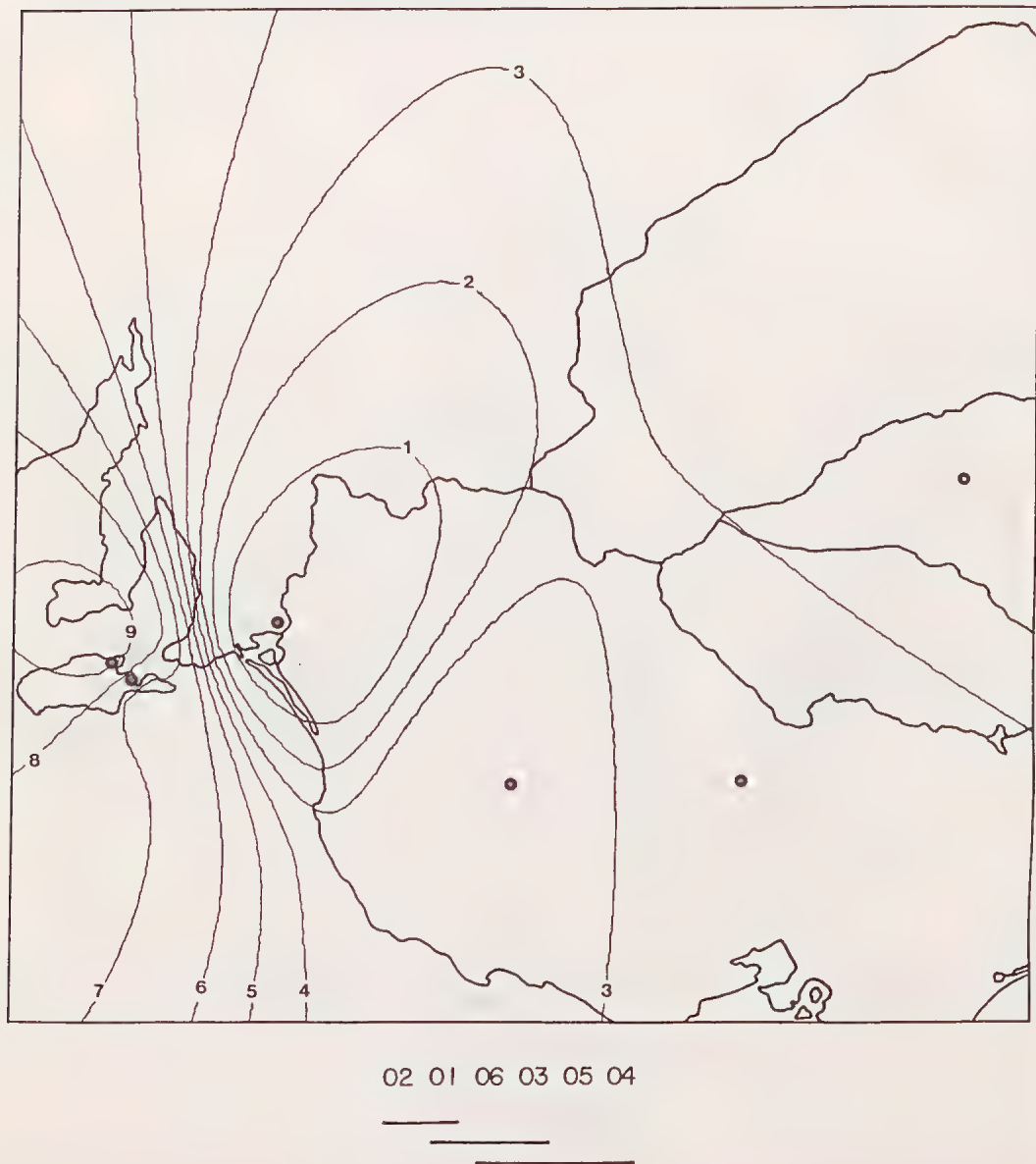


Fig. 50 Contour map (with summary of SNK test) of % composition of $C_{10}H_{16}O$ (character 15) for populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.03; 2 = 0.09; 3 = 0.15; 4 = 0.21; 5 = 0.27; 6 = 0.33; 7 = 0.39; 8 = 0.45; 9 = 0.51.

a value of 2%, the small sample size in my study may have over-emphasized a chemical form rich in this compound, which is represented by certain individuals of the population.

To assess the extent to which the oil data supports the morphological data in explaining the pattern of geographic variation, the matrices of the Manhattan metric distances of both the leaf oil characters and the morphological characters (based on the same individuals) were compared by computing Pearson's correlation coefficient (r). The correlation coefficient for the comparison of the two matrices, based on all characters (except KHDI and STMX, refer p. 237), was only 0.3. However, a correlation coefficient of $r = 0.61$ resulted



Fig. 51. The composite differential formed from volatile leaf oil compounds in populations of *P. aspalathoides*. Contour symbols and values are: 1 = 0.09; 2 = 0.15; 3 = 0.22; 4 = 0.28; 5 = 0.34; 6 = 0.40.

from the comparison of the two matrices, based on those characters which had a significant *F*-test and a significant SNK test (both at the 0.01 level). Since the chemical characters appear to be under strict genetic control (Hanover 1966a, 1966b; Forsen & von Schantz, in Bendz & Santesson 1973; von Rudloff 1972b; Irving & Adams, in Runeckles & Mabry 1973), the regions of differentiation (Figs. 26 & 51), in particular the region of rapid change between the mainland and the Kangaroo Island populations, may reflect genotypic as well as phenotypic distinctness.

Function of volatile oils in *Prostanthera*

The function of terpenoids is very inadequately known and has often been regarded as obscure. For example, Bonner (1950) assigned no function to lower terpenoids, whereas Sandermann (1962) regarded terpenoids as waste products. Contrary to the above, Fraenkel (1959) concluded that the secondary compounds (in a number of families) repelled or attracted insects. A similar view was expressed by Briquet (1895) for the Labiatae. Recent biochemical and physiological studies have shown that many terpenoids participate in the metabolism of the plant (refer Loomis, in Pridham 1967). Other studies have further established probable functions for terpenoids (e.g. Ehrlich & Raven 1965; Goodwin, in Pridham 1967; Harborne 1972 (& papers therein), 1977 (& literature cited therein), 1978 (& papers therein); Langenheim 1969, 1981; Muller 1966; Nicholas 1973; Smith 1976; and Sondheimer & Simeone 1970). However, Nicholas (1973) concluded that 'there is no established role for any monoterpene with regard to its physiological or biochemical function *within* plant tissues'. Furthermore, because of the large number of terpenoids already known, it is unlikely that every one will have a specific function (Goodwin, in Pridham 1967). Smith (1976) suggests that the terpenoids are more likely to have a collective function.

Volatile oils as a defence against animals and insects

In *Prostanthera* I have noted that the foliage (particularly of sect. *Klanderia*) is not attacked by insects nor is it usually grazed by animals (p. 224). Whether or not the high concentration of volatile oils (in leaves, stems and calyces) is a definite insect-repellant and/or is unpalatable to animals, is not known. Oh *et al.* (1967) showed that monoterpenes, which are common in *Prostanthera* (refer Table 13; also Lassak 1980), inhibit digestion in deer and sheep. It is not clear, however, whether these effects are related to palatability differences (Harborne 1977). Harborne (1977) summarizes the feeding preferences of insects with respect to the known role of various chemicals as insect attractants and/or deterrents. Monoterpenes are frequently olfactory attractants, whereas a number of sesquiterpenes are important repellents. The importance of monoterpenes as feeding repellents is not clear (Harborne 1977).

Initial analyses of *P. monticola* and *P. walteri* (both sect. *Klanderia*) indicate that both of these species have relatively low quantities of volatile leaf oils. However, the foliage of both species was not grazed and it appeared to be free from insect attack. Therefore, the amount of oil does not appear to influence insect or animal feeding preferences.

Sumimoto *et al.* (1975; as summarized in Harborne 1977) found that the chemical insect repellent of *Pinus* was present only in very small amounts. Preliminary analysis of the leaves of *P. behriana* (sect. *Prostanthera* series *Subconcavae* Benth.) show that this species either lacks volatile leaf oils or these oils occur only in trace amounts. Similar to *P. monticola* and *P. walteri*, the foliage did not appear to be affected by insects. However, this species is sometimes grazed (presumably by kangaroos and rabbits). A few other species (also of sect. *Prostanthera* series *Subconcavae* Benth.), viz. *P. baxteri*, *P. nivea*, *P. saxicola* and *P. suborbicularis*, appear to lack volatile oils (Lassak 1980). At this stage, the evidence of volatile oils conferring possible unpalatability to grazers and acting as insect repellents (for *Prostanthera*) is inconclusive.

Volatile oils and pollination

Insect pollinated flowers typically have a floral scent (Bergström, in Harborne 1978; Faegri & van der Pijl 1979; Hills *et al.* 1972; Holman & Heimermann 1973; Thien *et al.* 1975). However, the flowers of sect. *Prostanthera* (which are insect pollinated) (p. 221) appear to lack floral odour (at least to human senses). I have noted that a number of species in this section (in particular *P. ovalifolia* and *P. lasianthos*) readily volatilize their essential oils, especially when in flower. It seems likely that the essential oils of the leaves, branches and calyces (in particular, the monoterpenes) may act as a general olfactory attractant which guides insects to the scentless flowers. However, until the presence or absence of floral odours in *Prostanthera* is verified using techniques similar to those of Bergström (in Harborne 1978) or Holman & Heimermann (1973), it is difficult to assess the importance of essential oil volatilization in relation to pollination. Since insects are extremely sensitive to small concentrations of volatile substances, 'flower odours are probably effective at relatively low concentrations' (Harborne 1977).

Systematic treatment

The following circumscription of *Prostanthera* section *Prostanthera* is based on the work of Bentham (1870). This brief description is offered so that the diagnostic features of the two sections can be more readily compared (refer Figs 52 & 53).



Fig. 52 *Prostanthera lasianthos*.—A. flower; B. open flower with half of calyx and corolla removed; C. distal view of corolla, androecium (after anthesis), style and stigma; D. calyx after fertilization; E. part of calyx removed to show two mericarps and style (all from cultivated material, Burrendong Arboretum).

a. *Prostanthera* Labill. sect. *Prostanthera*

Prostanthera Labill. sect. *Prostanthera*: Benth., Fl. austral. 5 (1870) 93 [as sect. '*Euprostanthera*']; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220 [as sect. '*Euprostanthera*']; C. Moore, Handb. fl. New S. Wales (1893) 350 [as sect. 'I'];—*Type species*: *Prostanthera lasianthos* Labill.

Calyx tube striate, lobes unequal in length. *Corolla tube* short, broad distally; *abaxial lobe* longer and more spreading than the erect *adaxial lobes*. *Fruit* with 4 mericarps enclosed by inward folded *abaxial calyx lobe*; *adaxial calyx lobe* usually recurved. Fig. 52.

Note: This section contains approximately 80 species. Although it is in need of revision, a systematic account is not included in this study.

b. *Prostanthera* Labill. sect. *Klanderia*

Prostanthera sect. *Klanderia* (F. v. Muell.) Benth., Fl. austral. 5 (1870) 105; C. Moore, Handb. fl. New S. Wales (1893) 352 [as sect. 'II']. *Klanderia* F. v. Muell., Linnaea 25 (1852) 426; Walpers, Ann. bot. syst. 5 (1858) 667;—*Type species*: *Prostanthera chlorantha* (F. v. Muell.) Benth.

Prostanthera sect. *Cryphia* (R. Br.) Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220; *Cryphia* R. Br., Prodr. 1 (1810) 508; Poir., in F. Cuvier (Ed.), Dict. sci. nat. 2nd ed. 12 (1819) 78; Sprengel, Linn. Syst. veg. ed. 16, 2 (1825) 704; Gen. pl. 2 (1831) 468; Benth., Labiat. gen. spec. (1834) 448; G. Don, Gen. hist. 4 (1837-8) 798; Endl., Gen. 8 (1838) 621; D. Dietr., Syn. pl. 3 (1842) 354; Walpers, Rep. bot. syst. 3 (1844) 764; *ibid* 3 (1845) 985; Benth., in DC., Prodr. 12 (1848) 558—Based on:—*P. serpyllifolia* (R. Br.) Briq. and *C. microphylla* R. Br.

Small shrubs, up to c. 2 m high, diameter up to 1 (-1.5) m. *Leaves* with margin \pm entire; venation usually not visible, sometimes faint. *Inflorescence* racemiform on leafy branches, uniflorescence monadic; prophylls 2. *Calyx* with 2 \pm equal lobes, margin entire. *Corolla* glabrous basally on outer surface, at least on that part enclosed by the calyx; *tube* long, \pm straight to incurved, gradually expanded distally, mouth \pm elliptic in outline, 4-8 mm wide along shortest axis, inner surface glabrous; *median adaxial* and *abaxial lobes* usually \pm equal in length, usually ovate to obovate, apices often rounded, *abaxial lobe* slightly recurved to reflexed, *adaxial lobe* extended forward, sometimes recurved to reflexed near apex, concave in section; *lateral lobes* usually shorter than median lobes, \pm triangular, spreading to reflexed, apices usually subacute to obtuse. *Stamens* 4; filaments ligulate to subterete, glabrous; anthers basifixed between lobes, 1-2.5 mm long, introrse, connective with small fringe at distal end of filament. *Disc* up to 1 mm long, diameter up to 1.5 mm. *Pistil* glabrous; ovary \pm cylindrical-ovoid to obovoid, 4-lobed, lobes 0.1-0.3 mm long, enlarging after fertilization; style terminal, slender, ligulate to terete; slightly curved, lying next to inner *adaxial* surface of corolla; stigma shortly bifid. *Fruit* of 4 mericarps, mericarps not enclosed by calyx lobes; seed \pm flattened, ellipsoid to oblong-ellipsoid, rarely sub-cylindrical, slightly incurved, 1-2.5 x 0.5-0.8 x 0.2-0.5 mm, thickened distally. Fig. 53.

Recognised taxa and their distribution

In this revision fifteen species are recognized in sect. *Klanderia* (viz. *P. aspalathoides*, *P. calycina*, *P. chlorantha*, *P. florifera*, *P. grylloana*, *P. incurvata*, *P. laricoides*, *P. monticola*, *P. patens*, *P. pedicellata*, *P. porcata*, *P. ringens*, *P. semiteres*, *P. serpyllifolia* and *P. walteri*). *Prostanthera* sect. *Klanderia* occurs in all mainland States of Australia (except the Northern Territory), but is absent from Tasmania (Fig. 53-II). The number of species of sect. *Klanderia* which occur in each State are: Queensland 2; New South Wales 6; Victoria 4; South Australia 5; and Western Australia 7. *P. serpyllifolia* ssp. *serpyllifolia* is confined to South Australia, whereas *P. serpyllifolia* ssp. *microphylla* occurs in New South Wales, Victoria, South Australia and Western Australia. *P. grylloana*, *P. incurvata*, *P. laricoides*, *P. patens*, *P. pedicellata* and *P. semiteres* are confined to Western Australia. *P. calycina*, *P. chlorantha* and *P. florifera* are confined to South Australia. *P. aspalathoides* occurs in all eastern mainland States plus South Australia. *P. monticola* and *P. walteri* occur in New South Wales and Victoria. *P. ringens* occurs in Queensland and New South Wales. *P. porcata* is restricted to south-eastern New South Wales.

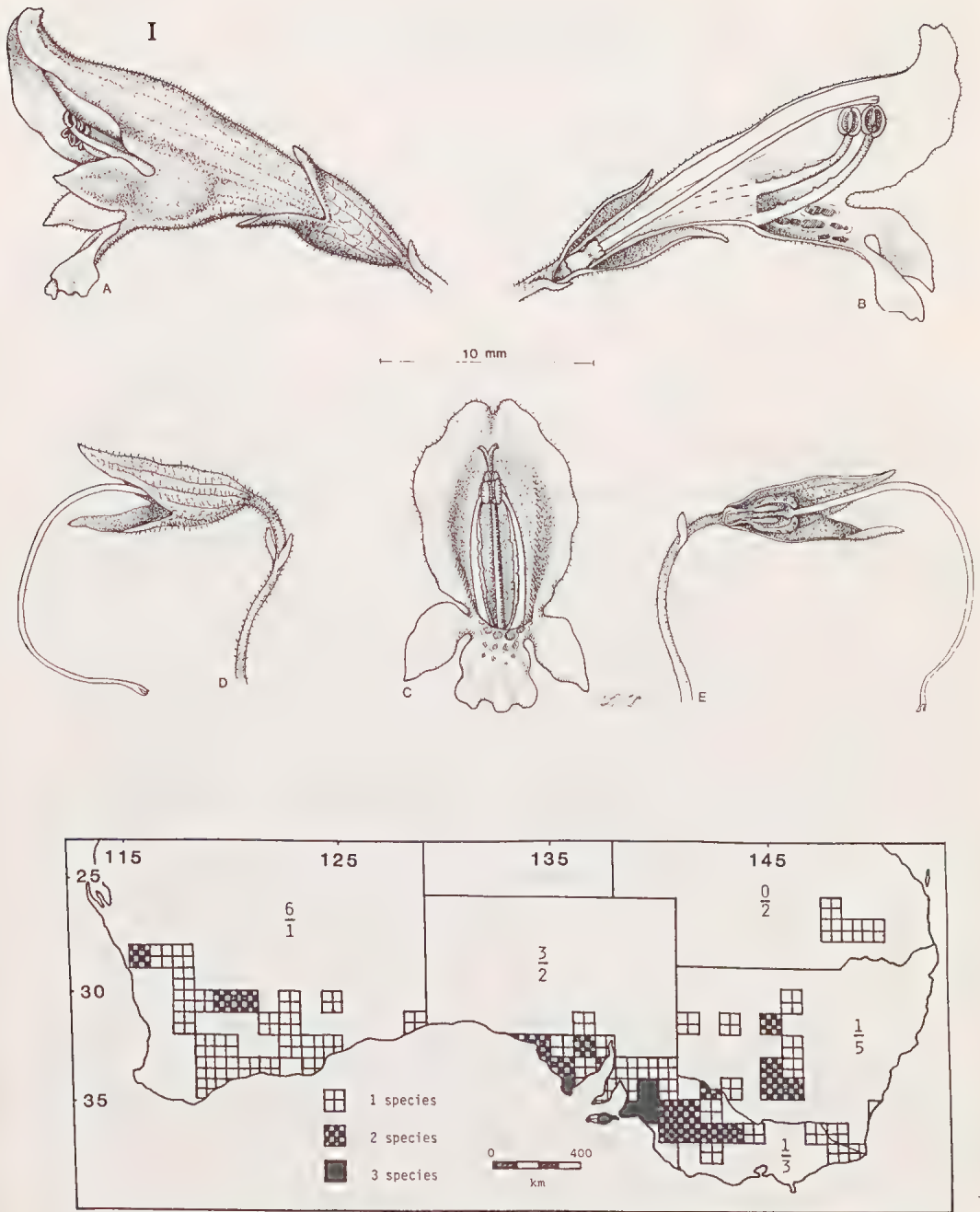


Fig. 53. Floral structure and species diversity of *Prostanthera* sect. *Klanderia*. I. *Prostanthera aspalathoides*.— A. flower; B. open flower with half of calyx and corolla removed; C. distal view of corolla, androecium, style and stigma, as seen from abaxial side; D. calyx after fertilization; E. part of calyx removed to show two mericarps and style (all Conn 3307). II. Species diversity of *Prostanthera* sect. *Klanderia* (number of species per 1° square).— above the hyphen the endemic species for each State, below the hyphen the non-endemic species.

Key to species

- 1a. Inner surface of calyx hairy, may be sparsely so, or if glabrous then pedicel* at least 9 mm long with branches glabrous and densely glandular; and corolla red 2
- 1b. Inner surface of calyx glabrous, sometimes with a few hairs near margin 8
- 2a. Leaves 5-13 mm long; lamina 15-50 mm long; corolla 30-35 mm long; prophylls 10-18 mm long (New South Wales, Victoria) 13. *P. monticola*
- 2b. Leaves up to 2.5 (-3) mm wide; lamina up to 20 mm long; corolla 12-27 mm long; prophylls 2 (-2.5) mm long (Western Australia) 3
- 3a. Outer surface of calyx hairy throughout (sometimes sparsely so) 4
- 3b. Outer surface of calyx glabrous or if hairy, then hairs restricted to distal part of calyx and then sparsely so 7
- 4a. Anther appendage absent; inner surface of calyx sparsely hairy; branches glabrous; pedicel* 7-13 mm long 7. *P. pedicellata*
- 4b. Anther appendage present; inner surface of calyx densely hairy; branches hairy (usually densely so); pedicel less than 3.5 mm long 5
- 5a. Leaves spatulate, conduplicate 12. *P. grylloana*
- 5b. Leaves \pm terete or ovate to oval; margin recurved so lamina often appearing oblong, never conduplicate 6
- 6a. Leaves less than 2 mm long; lamina length to width ratio less than 2; calyx lobes length to tube ratio greater than 0.5 3. *P. patens*
- 6b. Leaves at least 10 mm long; lamina length to width ratio (6-) 12-32; calyx lobes length to tube ratio less than 0.45 10. *P. laricoides*
- 7a. Branches hairy, sometimes restricted to two opposite lines along branches (rarely glabrous); pedicel up to 1.5 (-2) mm long; leaves usually incurved 8. *P. incurvata*
- 7b. Branches glabrous (rarely with an occasional hair); pedicel 3-15 mm long; leaves \pm straight to slightly recurved 9. *P. semiteres*
- 8a. Prophylls inserted at base or on lower half of pedicel; [anthopodium to a_1 axis ratio (1-) 2-7] (Queensland, New South Wales) 11. *P. ringens*
- 8b. Prophylls inserted at base of calyx or on upper half of pedicel; [anthopodium to a_1 axis ratio usually less than 1] 9
- 9a. Hairs irregularly ramose, \pm densely covering branches, leaves, pedicels and calyx (simple hairs may also be present) (South Australia) 1. *P. chlorantha*
- 9b. Hairs simple, sometimes with a few ramose hairs on calyx (Kangaroo Island populations of *P. serpyllifolia* ssp. *microphylla*), never on branches or leaves 10
- 10a. Hairs (of branches, leaves—particularly on margin and midrib of abaxial surface and calyx) stiff, straight, appressed; hair apex directed towards distal part of organ (Eyre Peninsula, South Australia) 4. *P. calycina*
- 10b. Hairs (of branches, leaves and calyx) \pm soft, recurved to reflexed, never appressed, frequently curled (widespread) 11
- 11a. Leaves \pm terete to linear-obovate 12
- 11b. Leaves ovate to narrowly ovate, sometimes suborbicular, never terete or linear-obovate 13
- 12a. Anther appendage 1-2.5 mm long; calyx 7-12 mm long (Gawler Ranges, South Australia) .. 6. *P. florifera*
- 12b. Anther appendage up to 0.3 (-0.5) mm long; calyx 5-7 mm long (widespread, absent from Gawler Ranges) 5. *P. aspalathoides*
- 13a. Branches quadrangular and 4-ridged, ridges adnate to base of petiole (SE New South Wales) .. 15. *P. porcata*
- 13b. Branches \pm terete, ridges absent 14
- 14a. Lamina (10-) 18-26 (-38) x 5-15 (-17) mm; petiole 2-5 (-8) mm long; venation faint; abaxial median corolla lobe 5-10 mm long; lateral corolla lobes (4-) 5-7 (-10) mm long (SE New South Wales and eastern Victoria) 14. *P. walteri*
- 14b. Lamina (1-) 1.5-13 x 0.5-4 (-6) mm; petiole absent or 0.4-2.5 (-5) mm long; venation not visible; abaxial median corolla lobe 3-4 mm long; lateral corolla lobes 1-4.5 mm long (widespread; in Victoria N & W of Great Dividing Range) 2. *P. serpyllifolia*

* Pedicel = a_1 axis + anthopodium

1. *Prostanthera chlorantha* (F.v. Muell.) F.v. Muell. ex Benth., Fl. austral. 5 (1870) 108; F.v. Muell., Fragm. 9 (1875) 162; *op. cit.* 10 (1876) 18; Woolls, Pl. New S. Wales (1885) 83; F.v. Muell., Key Vict. pl. 1 (1885) 42; *op. cit.* 1 (1887) 386; Tate, Trans. & Proc. Roy. Soc. S. Austral. 12 (1889) 111; Handb. fl. extratrop. S. Austral. (1890) 151, 252; C. Moore, Handb. fl. New S. Wales (1893) 353; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220; Dixon, Pl. New S. Wales (1906) 232; Guilfoyle, Austral. pl. (1911) 302; J.M. Black, Fl. S. Austral. ed. 1, 3 (1926) 492; *op. cit.* ed. 2, 4 (1957) 739, t. 1058; Hj. Eichler, Suppl. Black's fl. S. Austral. (1965) 269; Galbraith, Wildfl. SE. Austral. (1977) 326; Althofer, Cradle of Incense (1978) 124, 128, 129.

Lectotype (here chosen): *Fischer s.n.*, -?xi.1851, '*Prostanthera coccinea* ferd. Mueller var. *chlorantha*. Mount Barker Creek.', South Australia (MEL 41908—lower left specimen; islecto. MEL 41908—upper and centre right specimens, probable islecto. K, MEL 41906, MEL 41907). [refer Typification].

Klanderia chlorantha F.v. Muell., Linnaea 25 (1852) 426; Walpers, Ann. bot. syst. 5 (1858) 667.

Small shrub, up to 0.5 (-1) m high. *Branches* \pm terete, hairy; hairs ramose, with occasional simple hairs, 0.1-0.4 mm long; sparsely glandular. *Leaves* mostly arranged along short side branches, hairy; hairs ramose; *petiole* absent or if present, then less than 0.5 mm long; *lamina* suborbicular to broad-ovate, 1-3 (-4) \times 1-2.5 (-3) mm [lamina length to width ratio 1-1.8; distance of maximum width from base to total lamina length 0.1-0.35]; base rounded; margin entire, strongly recurved especially towards base and so lamina appearing deltoid; apex obtuse to rounded; venation not visible to indistinct. *Pedice* 5-13 mm long, slender, often glabrous basally, glabrescent for much of its length, distally with ramose hairs, sparsely glandular; *prophylls* inserted 0.5-3 mm from distal end of pedicel and so, usually not or occasionally just, overlapping basal part of calyx (sometimes alternately arranged), \pm linear-obovate 1-2 \times c. 0.5 mm long, slightly concave; abaxial surface and margin hairy (hairs ramose) and lepidote; adaxial surface glabrous; apex obtuse. *Calyx* 8-12 mm long, green, often with red-purple ribs (streaks), especially on tube; outer surface ramosely tomentose and lepidote; inner surface glabrous; *tube* 5-6 mm long; *lobes* triangular, 3-6 mm long, 2-4 mm wide at base; apex acute. *Corolla* 15-25 mm long, mauve, blue-green, dusty green-red to green-yellow with a pink tinge; outer surface sparsely hairy distally; hairs simple, c. 0.1 mm long; inner surface lacking dark spots, glabrous; *tube* 10-25 mm long; *abaxial median lobe* obovate, 2-5 mm long, c. 2 mm wide at base, slightly recurved; margin \pm entire to slightly irregular; apex obtuse to rounded, often emarginate; sinus up to 0.2 mm long; *lateral lobes* oblong-ovate, 4-5 mm long, c. 2 mm wide at base; margin entire, apex subacute; *adaxial median lobe-pair* suborbicular to broad-ovate, 5-10 mm long, c. 10 mm wide at base, slightly recurved distally; margin entire; apex rounded, sometimes emarginate; sinus up to 0.5 mm long. *Stamens* inserted c. 10 mm above base of corolla; filaments c. 5 mm long, with minute broad-triangular glandular trichomes; anthers 1.5-2 mm long; base of lobes minutely acuminate with acumen c. 0.1 mm long; apex obtuse to minutely acuminate, although appendage appearing absent, one side of connective usually slightly extended to form a minute basal appendage up to 0.03 mm long, sometimes with minute broad-triangular trichomes on appendage. *Pistil* 17-22 mm long; ovary c. 0.5 mm long, diameter c. 1 mm at base, lobes small, c. 0.1 mm long; style 15-18 mm long; stigma lobes up to 1 mm long. *Mericarps* 2-3 mm long, c. 1 mm wide distally, distally 0.4-0.6 mm extended beyond base of style. Figs 54 & 55.

Typification

The herbarium sheet MEL 41908 contains five specimens and two envelopes of fragments. The herbarium label (in Mueller's hand) corresponds with the locality details given in the protologue ('In montibus altis petraeis juxta amnem Mount-Barker-creek

sitis flumen Bremer versus . . . Fischer'; Mueller 1852, p. 426). There is close agreement between the brief description provided in the protologue and the lower left specimen of MEL 41908. Since Bentham examined this sheet (initials on label and on one envelope of fragments) this provides additional support for selecting a specimen from this sheet.

Distribution

South Australia—Murray Mallee, Mt Lofty Block (incl. Kangaroo Island), Southern Highlands and Plains [Eyre Peninsula].

Conservation status

This species appears to be conservationally endangered—Risk code = 3V, ?C.



Fig. 54. *Prostanthera chlorantha*.—A. twig and flowers; B. detail of leaves; C. irregularly branched hair; D. open corolla; E. stamens—ventral and dorsal views (all Conn 811).

Ecology

This species forms small populations of a few scattered plants, on sandy and loamy soils. It is commonly associated with *Banksia*, *Daviesia*, *Comosperma*, and *Leptospermum* shrubland.

Notes

This species is readily identified by the presence of irregularly branched hairs. *P. serpyllifolia* ssp. *microphylla* (from Kangaroo Island) is the only other taxon which has similar indumentum. However, the latter taxon has fewer branched hairs than those of *P. chlorantha*. Furthermore, in spp. *microphylla* the branched hairs only occur on the calyx. Other features including habit and leaf shape, suggest close affinities between these two taxa.

Common name: Green mint-bush (Ewart 1930)

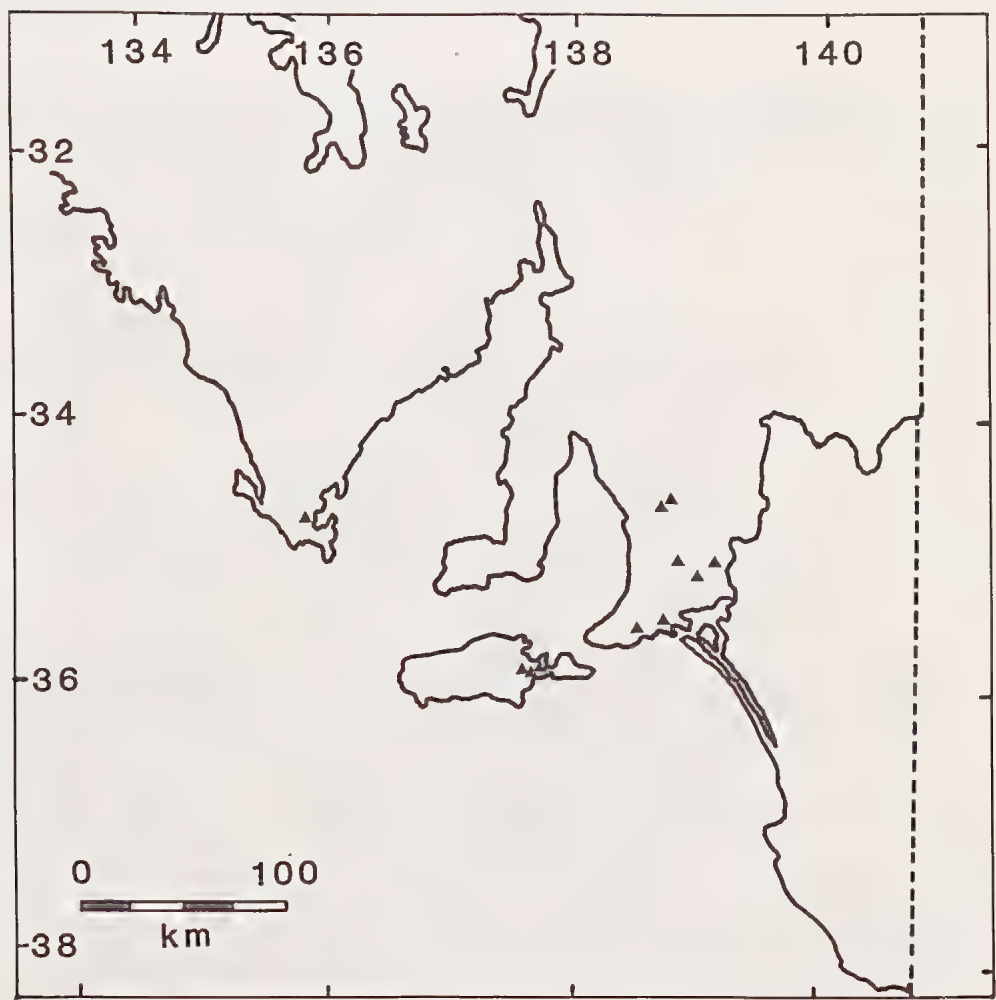


Fig. 55. Distribution map of *Prostanthera chlorantha*.

Selected specimens examined (c. 60 collections)

SOUTH AUSTRALIA.—Murray Mallee (Goolwa): *Hunt* 2649, 16.vii.1966, near Currency Creek, on main Goolwa to Strathalbyn road (AD). Mt Lofty Block: Peninsula Uplands (Barossa): *Purdie* 83, 4.ix.1966, back of Barossa Reservoir (AD); (Para): *Ising s.n.*, -x.1920, Para River near Gawler (AD); (Hahndorf): *Cleland s.n.*, 18.ix.1965, back road from Harrogate to Monarto (AD); (Sandergrrove): *Ising s.n.*, -vi.1925, Kinchina (AD); (Scotts Hill): *Mueller s.n.*, s. dat. Mt Barker Creek (MEL 41903-41905); (Inman Valley): *Carrick* 2959-2964, 21.x.1971, Victor Harbor (AD); Kangaroo Island (Mt Marsden): *Rogers s.n.*, -ix.1908, Retta's Lagoon (NSW); (Cygnet): *Eichler* 15262, 6.xi.1958, c. 13 kms S of Kingscote (AD); (Amberley): *P. Wilson* 889, 13.xi.1958, near Birchmore Lagoon (AD); (MacGillivray): *Carrick* 3509, 9.xi.1973, Kingscote Council Sand Reserve, near MacGillivray (AD). —[Eyre Peninsula] Southern Highlands and Plains (Lincoln): *Dixon s.n. in herb. Tate*, -x.1883, Port Lincoln (AD 96928849).

2. *Prostanthera serpyllifolia* (R. Br.) Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220. *Cryphia serpyllifolia* R. Br., Prodr. (1810) 508.

Type: R. Brown s.n. [*J.J. Bennett* 2360], anno 1802-5 [22.ii.1802 (R. Br. MSS.—microfilm copy at AD)], South Coast, Bay IX (also refer R. Br. MSS.) [Memory Cove (Stearn 1960)], southern Eyre Peninsula, South Australia (BM n.v.; probable duplicates in BRI, E, K, MEL 43408—left specimen, P, S). [refer Typification, p. 293; for full synonymy see ssp. *serpyllifolia*.

Small shrub, prostrate to erect, up to 0.5 (-1.6) m high. *Branches* ± terete, often slightly flattened distally, moderately to densely hairy, hairs (0.09-) 0.1-0.4 (-0.5) mm long, white; glandular; glands hemispherical, 1-35 (-90) glands/mm², rarely eglandular. *Leaves* sparsely to densely hairy, occasionally glabrous, sparsely to densely glandular; glands sunken in pits or raised and hemispherical; *petiole* absent or if present, then up to 1.5 (-3) mm long; *lamina* ovate to broadly elliptic (rarely suborbicular), to oblong-ovate, (1-) 1.5-13 x (0.5-) 0.7-4 (-6) mm, [length to width ratio (1-) 1.3-4 (-5.5), length of maximum width from base to total lamina length (0.07-) 0.2-0.6 (-0.7)]; base subattenuate to rounded; margin entire, recurved; apex obtuse to rounded; venation indistinct; base of midrib sometimes slightly raised on abaxial surface, sometimes slightly sunken on adaxial surface. *Pedice*l (0.8-) 1-5 (-13) mm long, ± terete, green or maroon, glabrous or hairy; hairs (when present) 0.09-0.4 (-0.5) mm long, white; *prophylls* inserted at base of calyx (rarely up to 1 mm from base of calyx), hence overlapping base of calyx, narrow-obovate to ± oblong, (1.1-) 2-4 (-5.3) x (0.3-) 0.5-0.8 (-1) mm [length to width ratio (2.5-) 3-7.5 (-12)], slightly concave, often recurved distally, rarely reflexed, glabrous or sparsely to densely hairy; hairs often restricted to margin; margin entire, usually slightly recurved; apex obtuse. *Calyx* (4.3-) 5-12 mm long, maroon or green; outer surface glabrous, or with a few scattered hairs to densely hairy; hairs white, sparsely to densely glandular; glands hemispherical; inner surface glabrous; *tube* 3-6 (-7) mm long; *lobes* ± broad-triangular, 1.5-4.5 (-5) mm long, 4-6 mm wide at base; margin entire; apex ± obtuse to rounded. *Corolla* 15-22 mm long, pink to mid-red, mid (metallic) blue-green, occasionally yellow; inner surface paler than outer surface; outer surface glabrous at base, sparsely to densely hairy distally, inner surface glabrous; *tube* 9-17 mm long; *abaxial median lobe* ± oblong-triangular to ± obovate, 3-4 mm long, ± recurved to reflexed; margin entire; apex obtuse to broadly rounded (when obovate), often emarginate; sinus up to 0.8 mm long; *lateral lobes* ± ovate to triangular, often narrowly so, sometimes obovate, 1-4.5 mm long, ± recurved to reflexed; margin entire, sometimes irregular distally; apex obtuse to subacute; *adaxial median lobe-pair* broadly triangular, 5-6.5 mm long, slightly incurved basally, often recurved distally; margin entire; apex obtuse, often slightly emarginate; sinus up to 0.3 (-0.5) mm long. *Stamens* inserted c. 8.5-9 mm from base of corolla; filaments c. 5.5-9 mm long, with a few glandular trichomes; anthers 1-2 mm long; base of lobes with a minute acumen up to 0.1 mm long; connective basally extended to form 1 or 2 short appendages (0.1-) 0.4-1.4 mm long, appendage rarely absent. *Pistil* 20-24 mm long; ovary 0.5-0.8 mm long, diameter at base 0.6-1 mm, lobes small, c. 0.1 mm long; style 19-23 mm long; stigma lobes up to 0.5 mm long. *Mericarps* 1.5-1.7 mm long, distally 0.5 mm extended beyond base of styles. Figs 56-58.

Typification

Brown (1810) does not cite any specimens for *Cryphia serpyllifolia* in the protologue. The locality is imprecisely cited as '(M)' [Ora Meridionalis—the South coast from Cape Leeuwin, Western Australia, to the islands of Bass Strait and Wilson's Promontory, Victoria (Stearn 1960)]. As pointed out by Burbidge (1956), such imprecise localities are useless for the determination of type localities. However, in Brown's MSS (microfilm copy held at AD, also refer Burbidge 1955), he cites the locality as 'Bay IX' [Memory Cove (Burbidge 1956; Stearn 1960)] and the date of collection as 'Feby. 22. 1802'.

Stearn (1960) gives a detailed account of the Brown herbarium. He suggests that it is best to select as the 'lectotype of a Brownian species the most complete individual specimen in the British Museum annotated by Brown . . .'. Therefore, I have delayed the choosing of a lectotype until I have examined Brown's material in the British Museum (see p. 211). J. Carrick (*in adnot.*) mentions a number of specimens held at BM (which I have not examined) which could be referable to the type. Of these, 'Brown 2360. *Cryphia serpyllifolia*, Bay IX South Coast' seems likely to be part of the original collection.

Distribution

Toowoomba, Queensland (Bailey 1901); New South Wales—Central Western Slopes, South Western Plains; Victoria—western Northern Plains, Mallee; South Australia—Murray Mallee, Mt Lofty Block (incl. Kangaroo Island), Yorke and Eyre Peninsulas; and Western Australia—south-eastern Eremaean, and South West.

Conservation status: considered not at risk.

Ecology

This species frequently occurs in Mallee communities, particularly on loamy and sandy soils which are overlying and associated with calcarenite (limestone), frequently with outcrops of calcrete.

Key to subspecies

- 1a. Lamina 4-13 x 1-4 (-6) mm, \pm flat (straight), usually not recurved or reflexed, leaves not clustered; petiole 0.4-1.5 (-3) mm long; pedicel 3-15 mm long; calyx (6-) 8-12 mm long 2.1 ssp. *serpyllifolia*
- 1b. Lamina (1-) 1.5-3 (-3.5) x 0.5-1 (-1.5) mm, recurved to reflexed and/or majority of foliage occurring on short lateral axes so that leaves appearing clustered; petiole absent or up to 0.3 (-0.5) mm long; pedicel 0.7-2.5 (-5) mm long; calyx (4.3-) 5-7.5 (-9.5) mm long 2.2 ssp. *microphylla*

2.1 ssp. *serpyllifolia*

Cryphia serpyllifolia R. Br., Prodr. (1810) 508; Sprengel, Linn. Syst. veg. ed. 16, 2 (1825) 704; G. Don, Gen. hist. 4 (1837) 798; Walpers, Rep. bot. syst. 3 (1844) 764; Benth., Labiat. gen. spec. (1834) 448; in DC., Prodr. 12 (1848) 588. [Refer Typification above].

P. serpyllifolia (R. Br.) Briq., in Engl. & Prantl. Nat. Pflanzenfam. 4, 3a (1895) 220; J.M. Black, Fl. S. Austral. ed. 1, 3 (1926) 492; *op. cit.*, ed. 2, 4 (1957) 739; Galbraith, Wildfl. SE. Austral. (1977) 325; Althofer, Cradle of Incense (1978) 146, 153.

P. coccinea F. v. Muell., [Sec. gen. report veg. colony (Oct. 1854) 13, *nom. nud.*] Trans. Phil. Soc. Victoria 1 (1855) 48, *p.p.*; J. Bot. Kew gard. misc. 8 (1856) 168, *p.p.*; Fragm. 6 (1868) 108, *p.p.*; *op. cit.* 9 (1875) 162, *p.p.*

Lectotype (here chosen): *Anon. s.n., s. dat.*, 'Prope m. Dutton. Fruticul. humil. diffus.', southern Eyre Peninsula, South Australia (MEL 43386). Other probable syntype: *Anon. s.n., s. dat.*, 'Near Spencers Gulf' (MEL 43876). [refer Typification, p. 295].

Branches moderately to densely hairy, 26-200 (-272) hairs/mm²; hairs (0.1-) 0.15-0.4 (-0.5) mm long, recurved to reflexed. *Leaves* arranged along the axis and branches, not clustered along short axes, sparsely to moderately hairy, often glabrous; hairs similar to



Fig. 56. *Prostanthera serpyllifolia* ssp. *serpyllifolia*. A. twig and flowers (Jackson 2641); B. twig and flowers (Tindale 589); C. glandular trichomes of branch; D. open corolla; E. stamens—ventral and dorsal views (Jackson 2641); F. distal view of corolla and androecium, gynoecium removed (Carrick 3911A).

those of branches; *petiole* 0.3-1.5 (-2) mm long; *lamina* broadly elliptic to ovate-oblong, 4-13 x 1-4 (-6) mm [length to width ratio (1.5-) 2-3.5 (-4), distance of maximum width from base to total lamina length (0.14-) 0.2-0.4 (-0.6)]; base obtuse to sub-attenuate; hairs similar to those of branches, \pm confined to upper surface, up to 30 (-80) hairs/mm². *Pedicel* (1.5-) 2.5-5 (-13) mm long, usually sparsely hairy or glabrous; hairs similar to those of branches. *Calyx* (6-) 8-12 mm long, usually maroon, sometimes green; outer surface glabrous or sparsely to moderately hairy, up to 15 (-22) hairs/mm²; hairs similar to those of branches, sparsely to densely glandular on outer surface; *tube* 4-6 (-7) mm long; lobes 3-4.5 (-5) mm long, 5-6 mm wide at base. *Corolla* red, often with yellow tinge distally, or metallic blue-green, occasionally yellow; *tube* 12-17 mm long. Fig. 56.

Typification

F. v. Mueller applied a broad concept to his 'consolidated' species, *P. coccinea*. His 'consolidated' species concept applied when he reduced a number of taxa to one species. Rather than use one of the existing names, he believed that the person who affected the reductions should 'choose a collective designation for the consolidated species' (von Mueller 1882, pp. vii. & viii). At various stages he included *P. aspalathoides*, *P. serpyllifolia*, *P. microphylla* and *P. caleyi* (Mueller 1855, 1868 & 1875). However, the majority of the annotated herbarium specimens are *P. serpyllifolia*. Contrary to this, most other authors appear to have applied a concept which is much closer to that of *P. microphylla*.

Of the material that I have examined, *Anon. s.n., s. dat.*, 'Prope m. Dutton. Fruticul. humil. diffus.' (MEL 43386) most completely fits the protologue. It is not known if Mueller would have regarded Mount Dutton as 'Spencer's Gulf' (as stated in the protologue). However, it is possible that he may have because he did not visit Eyre Peninsula (Churchill, *et al.* 1978) and so, may not have been aware of the exact locality of Mount Dutton. The brief description on the label (refer above) corresponds with the protologue, where Mueller describes this taxon as 'A low diffuse bush'. The only other specimen which is almost certainly a syntype of *P. coccinea* is *Anon. s.n., s. dat.*, 'Near Spencers Gulf' (MEL 43876).

Distribution

South Australia—[Yorke Peninsula] Southern Yorke Peninsula (Innes);—Western Pastoral: ?Gawler Ranges (*Sullivan s.n.*, MEL 43875);—[Eyre Peninsula] Central Mallee & Dunes (Kyancutta, Cleve, Hambidge, Tooligie, Blue Range, Hincks), West Coast (Drummond, Poldia, Mt Cooper, Inkster, Streaky Bay), Southern Highlands & Plains (Marble Range, Yalunda, Peake Bay, Lincoln); Western Australia—(Eremaean: Coolgardie, see p. 296).

Ecology

Occurs on calcarenite ridges and in sandy soils? to sandy loam soils of undulating calcreted plains in Mallee communities. At Innes National Park (Yorke Peninsula) it occurs on the limestone cliffs in shallow skeletal calcareous sands, whereas at Mount Greenly (Eyre Peninsula) it is associated with coastal shrubbery in loamy soils amongst granitic rocks.

Notes

At Mount Greenly (refer Fig. 31) and some populations at Port Lincoln (e.g. Kirton Point), there is a long pedicellate form of this subspecies [pedicel (6-) 9-15 mm long; calyx 6-9 mm long]. Elsewhere, the pedicel is usually up to 6 mm long. At Innes National Park (Yorke Peninsula) a few specimens have long pedicels (pedicel 3-10 mm long; calyx 7-12 mm long). However, when the calyx is at least 9 mm long (in the latter population), the pedicel is usually less than 6 mm long. The taxonomic significance of this form is not known, but it does not appear to warrant formal taxonomic status. It is of interest to note that it appears to be restricted to quartzites and granitic gneisses rather than calcarenites (refer

Johns 1961). Specimens referable to this long pedicellate form are:

SOUTH AUSTRALIA.—[Eyre Peninsula] Central Mallee Plains & Dunes (Lincoln): *Alcock* 807, 23.x.1965, Proper Bay Road (AD); *Black s.n., s. dat.*, Port Lincoln (AD 96909025); *Browne s.n., s. dat.*, Port Lincoln (MEL 43407); *Cleland s.n.*, 17.xii.1941, Proper Bay (AD 966031652); *Dixon s.n., -x.1883*, Port Lincoln (AD 96928848); *Wilson* 410, 12.x.1958, Kirton Point (AD, UC); *Wilson* 411, 12.x.1958, Kirton Point (AD, M, SYD, UC); *Specht* 2706, 10.xi.1960, Flora & Fauna Reserve, 15 km SSE of Port Lincoln (AD); (Drummond): *Conn* 684, 20.ix.1979, Mt Greenly (AD); *Williams* 2103, 18.iv.1965, Mt Greenly (AD).

The smaller leaved individuals are often difficult to distinguish from the larger leaved specimens of *ssp. microphylla* in the Arno Bay, Hincks National Park, Kimba, and Bascombe Well regions of Eyre Peninsula (South Australia). However, the lamina of the former subspecies are usually not reflexed and their pedicels are usually longer than those of *ssp. microphylla*.

One collection from Western Australia (*Newbey* 7135) appears to be intermediate between this subspecies and *ssp. microphylla*. Typical of *ssp. serpyllifolia* it has unclustered leaves, more or less flat lamina, and petioles up to about 1 mm long. However, the relatively small leaves and short pedicel (up to about 2 mm long) are more typical of *ssp. microphylla*.

Selected specimens examined (c. 95 collections)

SOUTH AUSTRALIA.—[Yorke Peninsula] Southern Yorke Peninsula (Innes): *Alcock* 4539, 6.x.1974, southern end of eastern boundary, Innes National Park (AD); *Conn* 1106, 11.x.1981, Ethel Bay, Innes National Park (AD).—[Eyre Peninsula] Central Mallee Plains & Dunes (Kyancutta): *Ising s.n.*, 9.ix.1938, Wudinna (AD 97650196); (Cleve): *Alcock* 1005, 7.xii.1966, Cleve Parklands (AD); (Hambidge): *Barker* 3639, 28.ix.1978, opposite turnoff to Red Bank, near Arno Bay (AD); *Wheeler* 561, 3.x.1967, c. 7 km SW of Bascombe Well Homestead (AD); (Tooligie): *Cleland s.n.*, 9.xi.1960, Tooligie Hill (AD); (Blue Range): *Alcock* 2202, 7.x.1968, c. 1.6 km N of Oak Amphitheatre, Blue Range (AD); (Hincks): *Symon* 6426, 11.x.1968, c. 3 miles N of Butler Gate on southern boundary of Hincks National Park (ADW); (Drummond): *Wilhelmi s.n., -i.1855*, Lake Hamilton (HBG, MEL 41900, W); (Polda): *Eichler* 19373, 9.x.1967, Mt Wedge (AD); (Mt Cooper): *B. Copley* 4801, 10.ix.1975, Mt Cooper (AD); (Inkster): *Canning* 23603, 30.viii.1968, 15 miles from Poochera (AD); (Streaky Bay): *Donner* 2484, 13.x.1967, c. 40 km S of Streaky Bay (AD); (Marble Range): *E. Jackson* 3656, 1.x.1979, slopes of South Block (AD); (Yalunda): *M. Clarke s.n.*, 5.x.1965, Hundred of Koppio (AD 966042262); (Lincoln): *Richards s.n., -x.1882*, Port Lincoln road (MEL 43874).

WESTERN AUSTRALIA.—Eremaean: Coolgardie: *Newbey* 7135, 16.viii.1980, Fraser Range, c. 75 km SSW of Zanthus (MEL, PERTH).

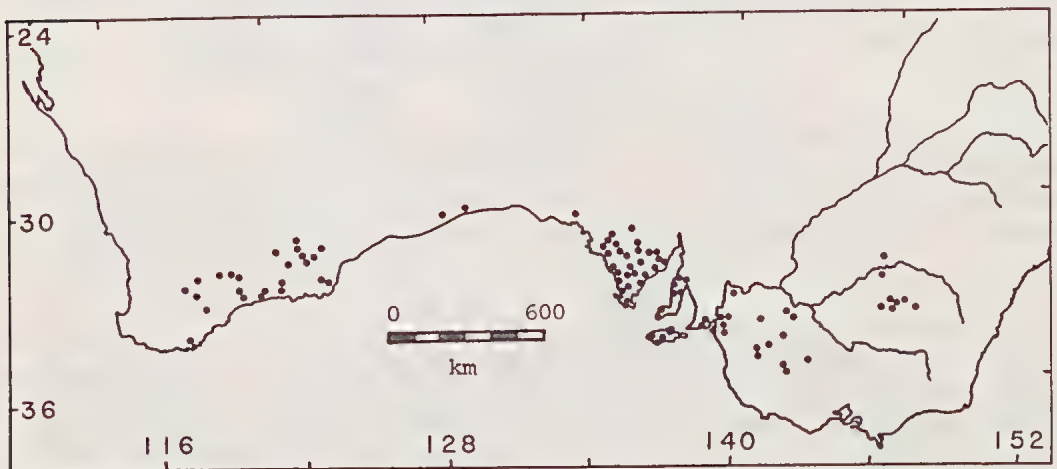


Fig. 57. Distribution map of *P. serpyllifolia*.

2.2 ssp. *microphylla* (R. Br.) Conn, stat. nov.

Cryphia microphylla R. Br., Prodr. (1810) 508; Sprengel, Linn. Syst. veg. ed. 16, 2 (1825) 704; Benth., Labiat. gen. spec. (1834) 448; G. Don, Gen. hist. 4 (1837) 798; Walpers, Rep. bot. syst. 3 (1844) 764; Benth., in DC., Prodr. 12 (1848) 559; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220 [as *P. microphylla* R. Br., nom. illeg.—latter homonym of *P. microphylla* A. Cunn. ex Benth. (1834)].

Type: *R. Brown* [*J. Bennett* 2359], anno 1802-5 [-ii.1802], South Coast, Bay 10 [Pt Lincoln (Stearn 1960)], southern Eyre Peninsula, South Australia (BM *n.v.*; probable dupl. in E—upper left specimen, K *n.v.*). [refer Typification, below].

P. microphylla A. Cunn. ex Benth., Labiat. gen. spec. (1834) 454; G. Don, Gen. hist. 4 (1837) 800; Walpers, Rep. bot. syst. 3 (1844) 767; Benth., in DC., Prodr. 12 (1848) 562; Fl. austral. 5 (1870) 106; F.M. Bailey, Queensl. fl. 4 (1901) 1204; Guilfoyle, Austral. pl. (1911) 305; F.M. Bailey, Compr. cat. Queensl. pl. (1913) 392; J.M. Black, Fl. S. Austral. ed. 1, 3 (1926) 492; Ewart, Fl. Victoria (1930) 982; C.A. Gardner, Enum. pl. austral. occid. (1931) 114; J.M. Black, Fl. S. Austral. ed. 2, 4 (1957) 738, 739; Hj. Eichler, Suppl. Black's fl. S. Austral. (1965) 269; Blackall & Grieve, W. Austral. wildfl. 3 (1965) 594; J.S. Beard, Descr. cat. W. Austral. pl. (s. dat. [Oct. 1965]) 94 [as *P. microphylla* (R. Br.) A. Cunn.]; Galbraith, Wildfl. SE. Austral. (1977) 325; Althofer, Cradle of Incense (1978) 74, 76, 82.

Lectotype (here chosen): [*A. Cunningham*], s. dat., 'Eurylean [Euryalean] scrub' near Lachlan River, New South Wales (K—lower left specimen; probable isolecto. *A. Cunningham* 225, anno 1817, 'Near Lachlan River. Euryalian [Euryalean—near Yalgogrin North and Weethalle (McMinn 1970, p. 21)] scrub' (typed label), New South Wales (MEL 43382—centre right specimen). [refer Typification, below].

P. coccinea F. v. Muell., [Sec. gen. report veg. colony (Oct. 1854) 13, nom. nud.] Trans. Phil. Soc. Victoria 1 (1855) 48, p.p., lectotype excl.; J. bot. Kew gard. misc. 8 (1856) 168, p.p.; Fragm. 6 (1868) 108, p.p.; op. cit. 9 (1875) 162, p.p.; Tepper, Trans. & Proc. Roy. Soc. S. Austral. 3 (1880) 31, 32, 43; Tate, Trans. & Proc. Roy. Soc. S. Austral. 3 (1880) 78; op. cit. 6 (1883) 145, 146, 165; F. v. Muell., Key Vict. pl. 2 (1885) 42; op. cit. 1 (1887) 385; Woolls, Pl. New S. Wales (1887) 385; Tate, op. cit. 12 (1899) 111; Handb. fl. extratrop. S. Austral. (1890) 151, 252; C. Moore, Handb. fl. New S. Wales (1893) 353; F. v. Muell. & Tate, Trans. & Proc. Roy. Soc. S. Austral. 16 (1896) 374; Dixon, Pl. New S. Wales (1906) 232; Pescott, Nat. fl. Victoria (s. dat. [1914]) 99. [refer Typification for ssp. *serpyllifolia* p. 295].

P. arenicola S. Moore, J. Bot. 59 (1921) 247; C.A. Gardner, Enum. pl. austral. occid. (1931) 114; Althofer, Cradle of Incense (1978) 74.

Holotype: *Sargent* 858, 22.x.1920, Gnowangerup, Western Australia (BM).

P. microphylla f. *aeruginosa* J.H. Willis, Vict. Natural. 73 (1957) 200; Ewart, Fl. Victoria (1930) 983 (as '*P. chlorantha* F. v. Muell.');

Holotype: *J.H. Willis* s.n., 29.viii.1955, 'Rock Holes bore', NW Victoria, near South Australian border (MEL 43383). [refer Notes].

Branches moderately to densely hairy, (25-) 30-170 (-290) hairs/mm²; hairs (0.09-) 0.12-0.46 (-0.52) mm long, recurved to reflexed, often appearing curled. **Leaves** usually clustered on short axes and arranged (unclustered) along long axes, sparsely to densely hairy; hairs similar to those of branches; leaves sessile or with *petiole* up to 0.3 (-0.5) mm long; **lamina** ovate to broadly elliptic, rarely narrowly ovate, (1-) 1.5-3 (-3.8) x (0.5-) 0.7-1.3 (-2.7) mm [length to width ratio (1-) 1.3-2.8 (-3.6), distance of maximum width from base to total lamina length (0.07-) 0.2-0.45 (-0.7)], often reflexed; base obtuse to rounded, sometimes \pm truncate; abaxial surface usually glabrous, sometimes with an occasional hair; adaxial surface glabrous or sparsely to densely hairy, (0-) 7-60 (-113) hairs/mm²; hairs similar to those of branches. **Pedicel** (0.8-) 1-3.5 (-4.8) mm long, sparsely to densely hairy; hairs similar to those of branches. **Calyx** (4.3-) 5-7.5 (-9.5) mm long, maroon or green; outer surface sparsely to densely hairy, rarely glabrous, (0-) 17-40 (-122) hairs/mm²; hairs similar to those of branches; **tube** 3-5 mm long; **lobes** 1.5-2.2 mm long, c. 4 mm wide at base. **Corolla** bright pink to mid-red, often white basally, and/or with yellow tinge distally, or light metallic blue-green; **tube** 9-14 mm long. Fig. 58.

Typification

Brown (1810) does not cite any specimens for *Cryphia microphylla* in the protologue. As for *C. serpyllifolia* (refer to Typification notes for ssp. *serpyllifolia*), the locality is imprecisely cited as '(M)' [South Coast]. The only source of additional information is Brown's original collection (as held at BM) because he does not mention this taxon in his manuscripts (microfilm copy held at AD).



Fig. 58. *Prostanthera serpyllifolia* ssp. *microphylla*. A. twig and flowers; B. glandular trichomes of branch; C. open corolla; D. stamens—ventral and dorsal views (all Carrick 3192).

For the same reasons as given under ssp. *serpyllifolia*, I have delayed the choosing of a lectotype until I have examined Brown's collections in the British Museum. J. Carrick (*in adnot.*) indicates that one collection of Brown's, held at the British Museum (which I have not examined): 'Brown 2359. *Cryphia microphylla*, Bay IX South Coast'—seems likely to be part of the original collection.

Since J.J. Bennett distributed duplicates of Brown's collections to the Royal Botanic Gardens, Kew, and to the Royal Botanic Garden, Edinburgh (and other herbaria) (Stearn 1960), the upper left specimen on a sheet at Edinburgh (E): 'R. brown, Iter Australiense, 1802-5 Presented by direction of J.J. Bennett, 1876. No. *Prostanthera microphylla*? Genus inter *Prostantheram* *Scutellariam*. South Coast Bays 9 & 10', can probably be regarded as a syntype, and hence, may be chosen as an islectotype.

A. Cunningham 225 (MEL 43382) is morphologically similar to *Anonymous* [*A. Cunningham*] (K). Furthermore, the locality information given in the protologue (Bentham 1834) and on the labels of the above two collections are similar. Therefore, the centre right specimen of *A. Cunningham* 225 (MEL 43382) is here regarded as a probable islectotype of *P. microphylla* A. Cunn. ex Benth.

The MEL material of *A. Cunningham* 225 is a mixed collection which has subsequently been mounted on separate sheets. MEL 43382 contains four specimens of *P. serpyllifolia* ssp. *microphylla*, MEL 61361 has one specimen of *P. aspalathoides*, and MEL 61362 has one specimen of an unidentified species of *Prostanthera* section *Prostanthera* [possibly *P. scutellarioides* (R. Br.) Briq.].

Distribution

New South Wales—Central Western Slopes, South Western Plains; Victoria—western Northern Plains, Mallee; South Australia—Murray Mallee, Mt Lofty Block (incl. Kangaroo Island), Yorke and Eyre Peninsulas; Western Australia—Eremaean: south-eastern Eucla, southern Coolgardie; South-West: Eyre, Roe, south-eastern Darling, southern Avon.

Ecology

Refer species. At Cape Cassini (Kangaroo Island), it occurs on limestone cliffs in shallow skeletal soils. Between Kimba and Whyalla it occurs in *Triodia* dominated grasslands (*Phillips* 160).

Notes

Most authors have applied a much narrower concept to *P. coccinea* than did Mueller. Although the exact concept used is not always clear, it seems that most authors regarded *P. coccinea* as very closely related to *P. microphylla*.

This subspecies is characterized by the small, usually ovate leaves which are recurved to reflexed. The calyx is consistently densely hairy in all Victorian populations and sparsely to densely hairy in New South Wales populations. In South Australia, the calyx is sparsely to densely hairy in those populations east of Murray Bridge (with few exceptions), Kangaroo Island (except at Cape Cassini), and central and northern Yorke Peninsula. Populations on northern Eyre Peninsula mostly have a hairy calyx, whereas those further South are more variable, such that the calyx is frequently glabrous. The populations in Western Australia are similar to those of Eyre Peninsula.

P. microphylla f. *aeruginosa* is reduced to synonymy because it is merely a colour form in a taxon which is extremely variable with respect to corolla colour.

Common names: Small-leaved mint-bush (Bailey 1883); Small-leaf mint-bush (Blackall & Grieve 1974, Ewart 1930, Willis 1973); Small mintbush (*Cunningham et al.* 1982).

Selected specimens examined (c. 230 collections)

NEW SOUTH WALES.—Central Western Slopes: *Kaspiew* 1342, 24.xii., Cowra (F).—South Western Plains: *Whaite* 2726, 21.ix.1963, 31 miles N of Hillston on Cobar road (NSW).

VICTORIA.—Mallee: *Beaglehole* 1064, -.x.1948, Hattah Lakes National Park (AD).—Northern Plains: *Dalton* s.n., 27.ix.1911, Dimboola District (LE); *Walter* s.n., 29.i.1889, West Wimmera (GH, MO, P).

SOUTH AUSTRALIA.—Murray Mallee: Upper Murray Lands (Pata): *Specht* 2360, 14.x.1960, c. 80 km SSE of Renmark (AD).—Northern Calcarene Ridges & Plains (Coonalpyn): *Beaglehole* 17538, 26.x.1967, c. 8 km W of Coonalpyn (AD); (Catnana): *Grivell* s.n., 1.x.1968, Yumali (AD 97050460) (Coorangie): *Sharrad* 241, 4.x.1959, Malinong (AD).—South East Mallee Heathlands (Billiatt): *van der Sommen* s.n., -.xi.1974, c. 16 km S of Paruna (AD 97449148); (The Big Desert): *Symon* 8660, 22.x.1973, Scorpion Springs Conservation Park (AD, ADW); (Moorlands): *Williams* 1037, 2.x.1960, c. 50 km SSE of Murray Bridge (AD); (Karoonda): *A. Burbidge* s.n., 26.ix.1971, c. 25 km E of Murray Bridge (AD 97142004).—Mt Lofty Block: Peninsula Uplands (Sander-grove): *Ising* s.n., -.vi.1925, Kinchina (AD 97249327).—Kangaroo Island (Stokes Bay): *Conn* 1073, 13.xi.1980, Cape Cassini (AD); (Parndana): *Eichler* 15172, 3.xi.1958, Cape Borda (AD); (Gantheaume): *B. & H. Conn* 1089-1092, 14.xi.1980, Kelly Hill Cave (AD).—Yorke Peninsula: Gulf Plains (Barung): *Donner* 1871, 12.x.1966, c. 11 km S of Bute (AD); (Boor Plains): *Phillips* s.n. (CBG 23839), 2.x.1965, 16 miles from Kadina towards Port Wakefield (AD); (Weetulta): *B. Copley* 4091, 15.ix.1973, c. 6 km SE of Moonta (AD).—Southern Yorke Peninsula (Urania): *Gill* 152, 29.ix.1890, near Maitland (MEL); (Corny): *Wrigley* WA/68 7745, 24.xi.1968, 12 miles from Corny Point (AD).—Western Pastoral: Gawler Uplands (Gawler): *Lay* 686, 29.ix.1972, c. 5 km S of Yarna Homestead (AD).—[Eyre Peninsula] Northern Myall Plains (Buckleboo): *Rohrlach* 625, 7.x.1959, 40 km WNW of Kimba (AD); (Thurlga): *Warnes* s.n., 1.ix.1968, Thurlga Station (AD 96850109); (Middleback Range): *Phillips* 160, 29.viii.1968, 41 miles from Whyalla towards Kimba (CBG 23621).—Central Mallee Plains & Dunes (Ironstone Hill): *Eichler* 19193, 28.viii.1967, 11 km E of Refuge Rockhole (AD); (Kimba): *Caulfield* 236, 29.ix.1955, Kimba (AD); (Pinkawillinie): *Orchard* 2138, 15.viii.1969, c. 56 km E of Kimba (AD, UC); (Kyancutta): *Chinnock* 2790, 4.x.1975, 29 km NW of Minnipa (AD); (Cleve): *Alcock* 632, 2.ix.1965, c. 17 km N of Arno Bay (AD); (Darke Peake): *Ising* s.n., 30.viii.1935, Darke Peake (AD 97249342); (Hambidge): *Kraehen-buehl* 2061, 9.x.1966, Hambidge National Park (AD); (Tooligie): *Cleland* s.n., 9.xi.1960, Tooligie Hill (AD 966071287); (Blue Range): *Wheeler* 748, 6.x.1968, slopes of Verran Hill (AD); (Hincks): *Symon* 6192, 8.x.1968, along North Diagonal road, Hincks National Park (ADW).—Southern Highlands & Plains (Butler): *Whibley* 7426, 2.x.1980, 11 km NNE of Ungarrd (AD); (Peake Bay): *Wilhelmi* s.n., s. dat., Tumby Bay (MEL 43385); (Mt Gawler): *Whibley* 1961, 27.viii.1967, c. 8 km NE of Port Neill (AD); (Lincoln): *J. Veitch* for *Beaglehole* 17574, anno c. 1950, Port Lincoln (AD).—West Coast (Drummond): *J. Veitch* s.n., 3.xi.1949, Mt Hope (AD 966051161); (Polda): *Ising* s.n., 16.ix.1938, Venus Bay (AD 97650199).

WESTERN AUSTRALIA.—Eremaean: south-eastern Eucla: *George* 8519, 15.x.1966, 3.5 miles E of Eucla (PERTH).—southern Coolgardie: *Armitage* 522, 4.x.1973, 68 miles S of Norseman (PERTH).—South West: southern Avon: *Gardner* 1998, 3.ix.1923, Dumbleyung (PERTH); Roe: *Royce* 8882, 23.x.1969, 3 miles N of Grass Patch (PERTH); south-eastern Darling: *Cronin* s.n., anno 1892, near King George's Sound (MEL 43868); Eyre: *Royce* 9302, 24.x.1970, Coppermine Creek, Fitzgerald River National Park (PERTH).

3. *Prostanthera patens* Conn, sp. nov.

Species nova Sectionis Klanderiae. *Frutices* parvi. *Rami* et *ramuli* spiniformes, moderate tomentosi, glandiferi. *Folia* dense tomentosa; *petiolus* usque ad 0.3 (-0.5) mm. longus; *lamina* ovata usque late elliptica 1.4-2.3 mm longa, 0.8-1.5 mm. lata, basi obtusa usque rotundata, margine integro, recurvo, apice obtuso usque rotundato. *Pedicellus* florum 1.5-3.2 mm. longus, dense tomentosus, *prophyllis* circa 1 mm. e basi calycis affixis, mox caducis. *Calyx* (5-) 6-7.7 mm. longus, extra et intra plus minus dense tomentosus, pilis 0.2-0.3 mm. longis; *tubus* 4-4.5 mm. longus; *lobi* plus minusve deltoidei, 2.4-3.5 (-4) mm. longi, circa 3.5 (-5.5) mm. lati, margine integro, apice obtuso usque late rotundato. *Corolla* 22-27 mm. longa, aurantiaca usque rubra, extra moderate usque dense tomentosa, intra in partibus distalibus sparsim tomentosa; *tubus* 11-17 mm. longus; *lobus abaxiali-medianus* late oblongus, 4-5.5 mm. longus, recurvus, margine integro, apice obtuso, saepe emarginato, sinu circa 0.2 mm. longo, *lateralibus* angusto-deltoideis usque plus minusve oblongis, 3-4 mm. longis, recurvis, margine integro, apice obtuso, saepe emarginato, sinu circa 0.2 mm. longo, *adaxiali-mediano* late obovato, 5-9 mm. longo, margine integro, apice rotundato, emarginato, sinu 0.2-0.6 mm. longo. *Stamina* circa 8 mm. e basi corollae affixa; filamenta 6-8 mm. longa; antherae circa 1.5 mm. longae, appendice 1-1.7 mm. longa. *Pistillum* 22-27 mm. longum; ovarium circa 0.6 mm. longum; stylus 20-25 mm. longus; lobis stigmatibus 0.4-0.5 mm. longis. *Fructis* non visis.

Holotypus: *Ashby* 5209, 24.viii.1975, east of Pindar, Avon botanical district, Western Australia (AD; iso MEL).

Small shrub, height unknown. *Branches* ± terete, stiff, spine-like, moderately hairy, particularly at nodes, (34-) 40 hairs/mm²; hairs 0.1-0.2 mm long, ± appressed [base of hair



Fig. 59. *Prostanthera patens*.—A. twig and flowers; B. open corolla; C. stamens—ventral and dorsal views (all *Alpin* 2551).

to first bend c. 0.03 (-0.05) mm; greatest distance hair from branch up to 0.05 mm], translucent to white; sparsely to moderately glandular; glands globular, raised. Leaf bearing branches short to long. *Leaves* clustered or arranged along branches, densely hairy, 128-220 hairs/mm², sparsely to moderately glandular, up to 20 glands/mm²; glands slightly raised; *petiole* \pm terete, up to 0.3 (-0.5) mm long; *lamina* ovate to broadly elliptic, often appearing \pm oblong because margin recurved, 1.4-2.3 x 0.8-1.5 mm [length to width ratio (0.9-) 1.5-2.8, distance of maximum width from base to total lamina length 0.19-0.43]; base obtuse to rounded; margin entire, recurved; apex obtuse to rounded; venation indistinct; midrib sometimes slightly raised on abaxial surface. *Pedice*l 1.5-3.2 mm long, \pm terete, usually maroon, densely hairy; hairs 0.1-0.2 mm long, appressed to suberect, white; *prophylls* inserted approximately halfway along pedicel [ratio of anthopodium length to a₁ axis length 0.8-1.3], not overlapping with base of calyx, soon deciduous, narrow-oblong, 0.8-1.3 x 0.3-0.5 mm [length to width ratio 1.6-4], hairy; margin entire; apex obtuse. *Calyx* (5-) 6-7.7 mm long, green to maroon; outer surface densely hairy, 128-215 hairs/mm²; hairs 0.2-0.3 mm long, \pm appressed, white; inner surface moderately to densely hairy, 56-185 hairs/mm²; *tube* 4-4.5 mm long; *lobes* \pm triangular, 2.4-3.5 (-4) mm long, c 3.5 (-5.5) mm wide at base; margin entire; apex obtuse to broadly rounded. *Corolla* 22-27 mm long, orange to pale red basally, red distally; outer surface moderately to densely hairy; hairs c. 0.2 mm long, with a few scattered glands to moderately glandular; inner surface glabrous at base, sparsely hairy above, especially on lobes; *tube* 11-17 mm long; *abaxial median lobe* broadly oblong, 4-5.5 mm long, recurved; margin entire; apex obtuse, often emarginate; sinus c. 0.2 mm long; *lateral lobes* narrow-triangular to oblong, 3-4 mm long, recurved; margin entire; apex obtuse; *adaxial median lobe-pair* broadly obovate, 5-9 mm long; margin entire; apex rounded, emarginate; sinus 0.2-0.6 mm long. *Stamens* inserted c. 8 mm above base of corolla; filaments 6-8 mm long, with scattered glandular trichomes; anthers 1.5 mm long; base of lobes with acumen c. 0.2 mm long; connective basally extended to form an appendage 1-1.7 mm long. *Pistil* 22-27 mm long; ovary c. 0.6 mm long, diameter at base 1-1.2 mm, lobes 0.3 mm long; style 20-25 mm long, sometimes with a faint median groove; stigma lobes 0.4-0.5 mm long. *Fruits* not known. Figs 59 & 68.

Distribution

Western Australia (Eremaean: Austin; South-West: Avon).

Conservation status: The conservation status of this species is not known—Risk code = 3K (?V).

Ecology

Little known of associations and geology. "Growing with *Wrixonia*" (Ashby 5220), "Not in heath country" (Ashby 5209), "ironstone scree on slope of B.I.F. ridge" (Blockley 488).

Notes

This new species was included in the *P. laricoides* complex as a result of various numerical analyses (in particular, refer Figs 6 & 8). However, numerical analysis (pp. 243-245) and a study of morphological variation (pp. 263-268) in this complex indicate that *P. patens* can be distinguished by many characters from the other species of the complex. The distinctness of *P. patens* is clearly illustrated in Figs 16-19. Therefore, the inclusion of this species in this complex is inappropriate. Its closest affinities appear to be with *P. serpyllifolia*. Both species have small leaves and long anther appendages. The spine-like branches of *P. patens* give this species a distinctive habit and the hairy inner surface of the calyx readily distinguish it from *P. serpyllifolia*.

Specimens examined

WESTERN AUSTRALIA.—Eremaean: Austin: *Alpin* 2551, 26.viii.1963, 25 miles N of Paynes Find (PERTH); *Beard* 2653, 10.viii.1965, N of Payne's Find (KP).—South-West; Avon: *Ashby* 5209, 24.viii.1975, E of Pindar (AD, MEL); *Ashby* 5220, 31.viii.1975, between Perenjori and the Inland Highway (Paynes Find Road) (AD, MEL); *Blockley* 488, 27.viii.1967, S of Paynes Find on Great Northern Highway (KP); *Burns* 1037/2, -x.1966, Morawa (PERTH); *Lullfitz* 2427, 9.ix.1963, 22 miles from Sandstone towards Mt Magnet (KP).—No locality: *Steenbohm s.n.*, -x.1961, *s. loc.* (PERTH).

4. *Prostanthera calycina* F. v. Muell. ex Benth., Fl. austral. 5 (1870) 107; Tate, Trans. & Proc. Roy. Soc. S. Austral. 3 (1880) 78; *op. cit.* 12 (1889) 111; Handb. fl. extratrop. S. Austral. (1890) 151, 252; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220 (as '*P. calicina*'); J.M. Black, Fl. S. Austral. ed. 1, 3 (1926) 492; *op. cit.* ed. 2, 4 (1957) 738; Galbraith, Wildfl. SE. Austral. (1977) 325; Althofer, Cradle of Incense (1978) 78, 80, 82.

Lectotype (here chosen): *Warburton s.n.*, *s. dat.*, Venus Bay, Eyre Peninsula, South Australia (MEL 41899). Other syntypes: *Wilhelmi s.n.*, *s. dat.*, Coast ranges to the west of Lake Hamilton, Port Lincoln (MEL 41900); *Wilhelmi s.n.*, *s. dat.*, Port Lincoln (MEL 41901). [refer Typification].

Small \pm prostrate shrubs, c. 0.5 m high. *Branches* \pm terete, often slightly flattened distally, often with faint grooving on internodes (from one leaf axis to the next node alternatively) moderately to densely hairy, 54–117 hairs/mm², hairs (0.1–) 0.3–0.4 (–0.5) mm long, stiff and straight (for most of length), appressed [base of hair to first bend usually less than 0.05 mm long; greatest distance hair from stem is less than 0.8 (–1) mm]; hair apex directed towards distal part of branches; sparsely glandular, up to 18 glands/mm². *Leaves* arranged along the axis and branches, not clustered on short shoots, usually sparsely, rarely densely hairy, occasionally glabrous; hairs similar to those of branches; *petiole* 0.8–1.4 mm long, \pm flattened, densely hairy, similar to those of branches; *lamina* elliptic to ovate-oblong, 4–14 x 3–5 mm [length to width ratio 1.4–3.8, ratio of distance of maximum width from base to total lamina length 0.4–0.6]; base obtuse to subattenuate; margin entire; apex obtuse to rounded; hairs \pm restricted to margin and midrib of abaxial surface, \pm confined to margin and apex of adaxial surface, up to 30 hairs/mm², similar to those of branches; venation indistinct or not visible. *Pedicel* 2.5–4.5 (–7) mm long, often maroon, densely hairy; hairs similar to those of branches; *prophylls* inserted at base of calyx, hence overlapping basal part of calyx, narrow-obovate to \pm oblong, 1.5–4 x c. 0.5 mm [length to width ratio (3–) 5–7.5], slightly concave, densely hairy, at least near base, sparsely hairy at apex; hairs sometimes restricted to margin; apex obtuse. *Calyx* 8–14 mm long, usually maroon, sometimes green; outer surface sparsely to moderately hairy, particularly along veins, up to 15 hairs/mm²; hairs similar to those of branches, moderately glandular on outer surface, 9–17 glands/mm²; inner surface glabrous; *tube* 6–8 mm long; *lobes* \pm triangular, 4–6 mm long, 5–7 mm wide at base; apex obtuse to broadly rounded. *Corolla* 17.5–22 mm long, red; outer surface distally sparsely to moderately hairy; hairs c. 0.1 mm long; inner surface glabrous; *tube* 13–15 mm long; *abaxial median lobe* \pm obovate, c. 4 mm long, c. 3 mm wide, \pm recurved to reflexed; margin entire; apex rounded; *lateral lobes* narrow, \pm triangular to ovate, c. 3 mm long, \pm recurved to reflexed; margin entire; *adaxial median lobe-pair* broadly triangular, c. 5 mm long; margin entire; apex obtuse, sometimes slightly emarginate; sinus up to 0.2 mm long. *Stamens* inserted c. 8.5 mm above base of corolla; filaments c. 5.5 mm long, with a few scattered minute glandular trichomes; anthers 1.5–2 mm long; base of lobes with minute acumen c. 0.06 mm long; connective extended to form a short basal appendage (0.1–) 0.4–0.8 mm long. *Pistil* 12–15 mm long; ovary 0.5–0.7 mm long, diameter c. 0.6–1 mm at base, lobes small, c. 0.1 mm long; style 11–14 mm long, sometimes with faint median groove; stigma lobes up to 0.3 mm long. *Fruit* unknown. Fig. 60.



Fig. 60. *Prostanthera calycina*.—A. twig and flowers (Weber 6210); B. twig and flowers; C. hairs on branch (all Warburton s.n.).

Typification

Bentham (1870) cited two collections in the protologue of *P. calycina* (viz. *Wilhelmi*, Port Lincoln; and *Warburton*, Venus Bay). The specimen collected by *Warburton* (as held at MEL) has one mature (open) corolla, whereas the *Wilhelmi* collections (two sheets at MEL) have old calyces and a few young buds. The *Warburton* collection and *Wilhelmi* (MEL 41901) specimen were examined by Bentham. Since Bentham described the corolla in the protologue, the *Warburton* collection (which has mature corollas) is here chosen as the lectotype.

Distribution

South Australia—western coastal and southern Eyre Peninsula: West Coast (Polda, Drummond, Edillie, Lincoln), Central Mallee and Dunes (Ceduna).

Conservation status

This species is possibly at risk (Risk Code = 2K, [Conn, in] Leigh *et al.* 1981, pp. 49 & 86).

Ecology

Occurs on calcarenite ridges and in sandy loams of undulating calcreted plains in Mallee communities. Commonly associated with *Eucalyptus incrassata*, *E. oleosa*, *E. socialis*, and frequently with *Melaleuca*, *Pittosporum*, *Santalum acuminatum*, and various shrubs (such as *Grevillea*, *Hakea* and *Spyridium*).

Notes

This species has a very distinctive hair type which is not found in any other taxon of this section (sect. *Klanderia*). The hairs are appressed, straight for most of their length, stiff, and directed towards the distal part of the organ on which they occur. It has its closest affinities with *P. serpyllifolia*. The relatively large calyx is a useful secondary feature which distinguishes this species from *P. serpyllifolia* ssp. *microphylla*. For further details on the relationship of this species with *P. serpyllifolia*, refer 'Numerical analysis of the *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex' and 'Morphological variation in the *Prostanthera calycina*—*P. microphylla*—*P. serpyllifolia* complex'.

Selected specimens examined (15 collections)

SOUTH AUSTRALIA.—[Eyre Peninsula] Central Mallee & Dunes (Ceduna): *Richards s.n.*, anno 1883, Fowler's Bay (MEL 41898).—West Coast (Polda): *Richards s.n.*, anno 1887, between Port Lincoln & Streaky Bay (MEL 43873); (Drummond): *Wilhelmi s.n.*, -i.1855, Lake Hamilton (HBG, MEL 41900, W); (Edillie): *Phillips* 6653, 27.viii.1964, 1 mile from Wanilla, towards North Shields (AD); (Lincoln): *Wilhelmi s.n.*, s. dat. [anno 1885], Port Lincoln (MEL 41901).

5. *Prostanthera aspalathoides* A. Cunn. ex Benth., Labiat. gen. spec. (1834) 453; G. Don, Gen. hist. 4 (1837-8) 799; D. Dietr., Syn. pl. 3 (1842) 427; Walpers, Rep. bot. syst. 3 (1844) 767; Benth. in DC., Prodr. 12 (1848) 562; Fl. austral. 5 (1870) 107; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4, 3a (1895) 220; J.M. Black, Fl. S. Austral. ed. 1, 3 (1926) 491; Ewart, Fl. Victoria (1930) 982; J.M. Black, Trans. & Proc. Roy. Soc. S. Austral. 55 (1931) 141; Fl. S. Austral. ed. 2, 4 (1957) 738, t. 1057; Hj. Eichler, Suppl. Black's fl. S. Austral. (1965) 269; Blombery, A guide to native Austral. pl. (1967) 309; Cochrane *et al.*, Flowers & pl. Victoria (1968) 53, fig. 128; Galbraith, Wildfl. SE. Austral. (1977) 325, pl. 27; Holliday & Watton, Austral. native shrubs (1978) 182 & 183, Althofer, Cradle of Incense (1978) 74, 75, 77, 79, 82 & 83.

Lectotype (here chosen): *A. Cunningham* 224, 24.v.1817, 'Dwarf shrub, Mr Oxley's first

expedition, down Lachlan River, on barren rugged hills' (K; probable isolecto: *A. Cunningham* 224, anno 1817, New South Wales, near Mount Aiton, BM, MEL 42918). [refer Typification].

P. coccinea [non F. v. Muell., Trans. Phil. Soc. Victoria 1 (1855) 48] F. v. Muell., Fragm. 6 (1868) 108, *p.p.* lectotype excl. [refer 'Typification' for *P. serpyllifolia* ssp. *serpyllifolia*, p. 295].

P. eriocalyx Gand., Bull. Soc. Bot. France, 65 (1918) 6.

Holotype: Walter s.n., -x.1892, 'N. West Victoria' (LY; iso in NSW). [refer Tindale in McGillivray (1973, p. 352)].

P. patula Gand., *loc. cit.*

Holotype: Sutton s.n., -x.1905, 'Australia. Wimmera, Victoria' (LY; iso in NSW). [refer Tindale in McGillivray (1973), p. 352]].



Fig. 61. *Prostanthera aspalathoides*.—A. twig and flowers; B. open corolla; C. stamens—ventral and dorsal views (all Carrick 2944).

Small shrub, 0.3-1 m high. *Branches* \pm terete, densely hairy; hairs c. 0.1 mm long, glandular. Leaf bearing branches short to long, when short, leaves often densely clustered at nodes of axis, when long, branches 2-4 mm long, then leaves spread out along branches. *Leaves* glabrous or sparsely tomentose, 0-40 (-66) hairs/mm²; hairs (0.05) 0.1-0.3 mm long, glandular, 15-50 (-100) glands/mm²; *petiole* absent or if present, then less than 0.5 mm long; *lamina* terete to compressed-terete, oblong-linear, linear-elliptic to linear-obovate, (1.5-) 2-6 (-10) x 0.5-1 mm [length to width ratio 3-6 (-10), distance of maximum width from base to total lamina length 0.07-0.92]; base slightly attenuate; margin entire, recurved when lamina subterete; apex obtuse to rounded; venation not visible. *Pedicel* 2-3 mm long, tomentose to glabrous; *prophylls* inserted near distal end of pedicel, and so overlapping basal part of calyx, narrowly oblong, 2-3 mm long, concave; abaxial surface sparsely tomentose, especially near margin, adaxial surface frequently sparsely fimbriate; apex obtuse. *Calyx* 5-7 mm long; outer surface sparsely to densely hairy, rarely glabrous; inner surface glabrous; *tube* 3-4 mm long; *lobes* broadly lanceolate to \pm triangular, 2-3 mm long, c. 3 mm wide at base; apex obtuse. *Corolla* 10-20 mm long, red, pink-red, orange, rarely yellow; outer surface distally hairy; inner surface usually with dark red spots on lower lips; *tube* 8-11 mm long; outer surface distally sparse to densely hairy; *lobes* sparsely hairy on outer surface; inner surface glabrous; *abaxial median lobe* obovate, slightly bilobed, 2-3 mm long, 2-4 mm wide at base; margin entire to irregular; apex obtuse to slightly bilobed; sinus up to 1 mm long; *lateral lobes* ovate to oblong-ovate, or \pm triangular, 1.5-3 (-4) mm long, 1.5-2 (-3) mm wide at base; *adaxial median lobe-pair* \pm ovate, often slightly 3-lobed, 5-8 mm long, 6-8 mm wide at base; apex obtuse, sometimes emarginate; sinus up to 0.5 mm long. *Stamens* inserted c. 10 mm above base of corolla; filaments 6-8 mm long, with broad-deltoid glandular trichomes; anthers 1.5-2 mm long, although appendage appearing absent, one side of connective usually extended to form a minute basal appendage up to 0.3 (-0.5) mm long, sometimes with broad-deltoid trichomes on appendage. *Pistil* 17-18 (-25) mm long; ovary 1-1.5 mm long, diameter c. 1 mm at base, lobe small, c. 0.3 mm long; style 15-20 (-23) mm long; stigma lobes up to 1 mm long. *Mericarps* 2-2.5 mm long, distally 0.5-1 mm extended beyond base of style. Figs 61-63.

Typification

Bentham (1834) cited '*A. Cunningham*' as the collector of the type of *P. aspalathoides*. There is close agreement between the brief description provided in the protologue and *Cunningham* 224. Furthermore, the herbarium label on the K sheet (p. 306) corresponds with the locality given in the protologue ('in collibus aridis sterilibus ad fluvium Lachlan'; Bentham 1834, p. 454). Therefore, *Cunningham* 224 (K) is here chosen as the type for this species.

Distribution

Queensland (Maranoa—*R. Jordan s.n.*, -viii.1953, St George), New South Wales (Central Western Slopes, South Western Plains, South Far Western Plains), Victoria (Mallee, Northern Plains) and South Australia (Murray Mallee, Mt Lofty Block—(incl. Kangaroo Island), Gulf Plains—[Yorke Peninsula], Northern Myall Plains and Central Mallee and Dunes—[Eyre Peninsula].

Conservation status: considered not at risk.

Ecology

Occurs in open Mallee communities (*Eucalyptus incrassata*, *E. socialis*) with open understorey commonly of *Melaleuca lanceolata*, *M. uncinata*, *Triodia* sp. and other heathland plants (*Barker* 4133; *Beaglehole* 28862, 29015, 29555), occasionally with *Callitris preissii* (*Conn* 1040; *Melville* 1085), frequently in roadside communities. It occurs on sandstones and shales (*Melville* 1310), amongst sandstone outcrops (*Beaglehole* 29015),



Fig. 62. *Prostanthera aspalathoides*.—A. twig and flowers; B. open corolla; C. stamens—ventral and dorsal views (all from cultivated material, Adelaide Botanic Gardens).

on red sandy loams (*Conn* 1042), overlying granite (*Brickhill s.n.*, 3.x.1979; *Conn* 775) or in shallow, calcareous soils (*Conn* 1043). Often in sandy soils with high 'buckshot' gravel content (*Conn* 703), less commonly occurring in soils with high clay content.

Note

There is considerable variation in the size of the leaves of *P. aspalathoides* (refer Figs 61A & 62A). For example, *Ising s.n.*, 9.ii.1937 (AD 966081719); *Kraehenbuehl* 913 (AD); and *Wheeler* 457 (AD, MEL) have very small leaves (2-2.5 x c. 0.7 mm) similar to *P. serpyllifolia* ssp. *microphylla*, whereas *Blaylock* 1306 (A, AD) has very long leaves (11-20 x 0.6-1.2 mm). In the Waikerie and Billiatt National Park areas of South Australia, the leaves are slightly flattened narrow-elliptic, similar to *P. serpyllifolia* ssp. *serpyllifolia*. However, *P. aspalathoides* usually has the leaves crowded on short shoots, e.g. *Aitkens s.n.*, 24.x.1974 (AD 98108051, MEL), *Carrick* 3306, 3307 (AD, MEL), and *Whibley* 3645 (AD, MEL), whereas those of *P. serpyllifolia* are arranged along the long axes.

This species is closely related to *P. florifera* (refer pp. 310-313). It differs from the latter by having a much shorter anther appendage (up to 0.5 mm long cf. 1-2.5 mm long for *P. florifera*) and usually smaller calyces (5-7 mm long cf. 7-12 mm long for *P. florifera*). Although the length of the anther appendage of *P. aspalathoides* is short, it is quite variable: appearing absent (e.g. Fig. 61C) or up to 0.3 (-0.5) mm long (e.g. Fig. 62C).

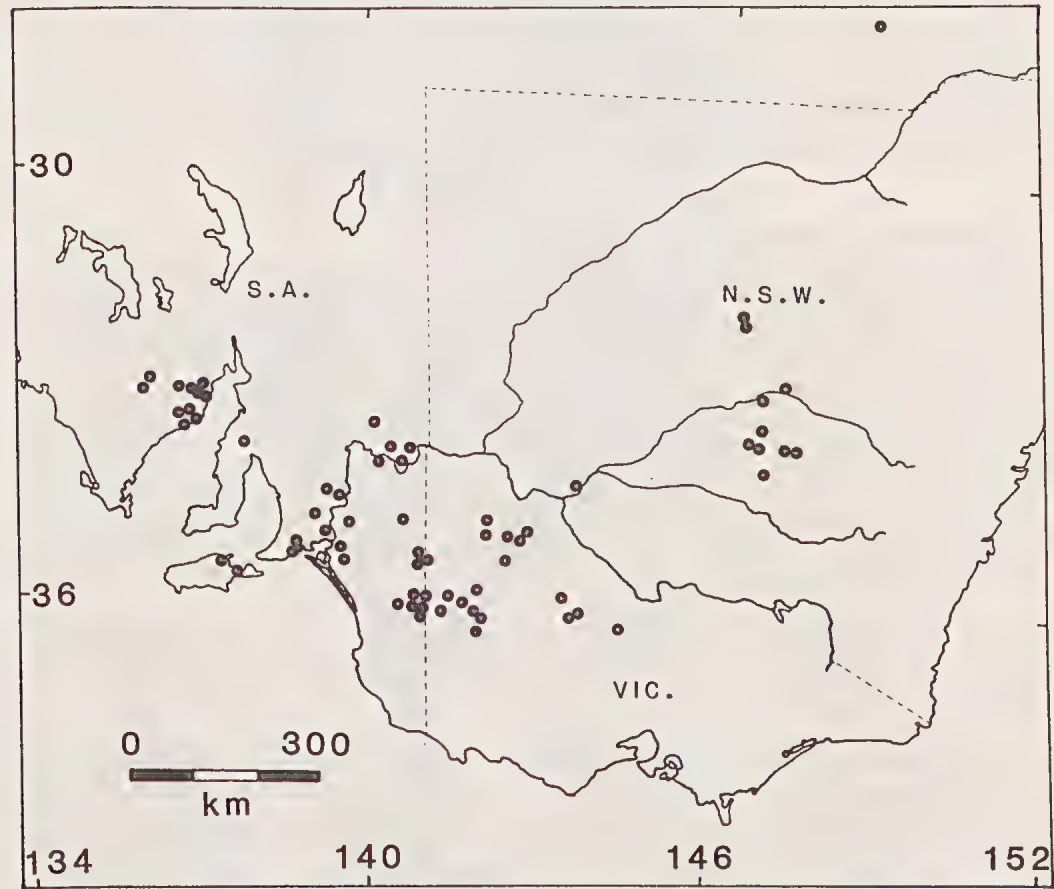


Fig. 63. Distribution map of *Prostanthera aspalathoides*.

Common name: Scarlet mint-bush (mintbush) (Blackall & Grieve 1974, Cunningham *et al.* 1982, Ewart 1930, Willis 1973).

Selected specimens examined (420 collections)

NEW SOUTH WALES.—Central Western Slopes: *Tindale s.n.*, -x.1963, 5 miles from W. Wyalong (A, AD 96401023, NSW 63772).—South Western Plains: *Conn* 760-768, 22.viii.1980, 12-15 km E of Rankin Springs (AD, MEL).—South Far Western Plains: *Phillips CBG* 23840, 15.ix.1965, 9 miles from Balranald (AD 97001168).

VICTORIA.—Mallee: *Beaulehole* 28862, 2.x.1968, Dattuck track, Wyperfeld National Park (AD).—Northern Plains: *B. & H. Conn* 703, 31.x.1979, 22 km NNE of Bendigo (AD); *Morris* 1527, 14.x.1926, Wederburn (NSW).

SOUTH AUSTRALIA.—Murray Mallee: Upper Murray Lands (Parcoola): *Munir* 5059, 5060, 26.ix.1971, c. 16 km N of Overland Corner (AD); (Renmark): *Reid s.n.* 26.iii.1958, Calperum station (AD 97348358); (Holder): *Donner* 3693, 26.ix.1971, c. 15 km W of Waikerie (AD); (Blanchetown): *Barker* 4133, 21.viii.1980, c. 6.5 km SW of Walkers Flat ferry crossing (AD); (Towitta): *Kraehenbuehl* 184, 31.vii.1960, river Marne Gorge (AD); South-East Mallee Heathlands (Billiatt): *Carrick* 3306-3309, 14.xi.1972, Billiatt National Park (AD); (Pinnaroo): *J.M. Black s.n.*, 12.x.1981, Pinnaroo (AD 96909064); (Karoonda): *J.M. Black s.n.*, 10.x.1910, Lameroo (AD 96909004); Moorlands: *Williams* 1039, 2.x.1970, between Malinong & Coomandook (AD); (The Big Desert): *Sharrad* 1095, 29.viii.1961, 30 miles from Pinnaroo (AD); (Cannawigara): *Wilson* 2089, 29.viii.1961, c. 65 km N of Bordertown (AD); (Bordertown): *Hunt* 234, 15.x.1961, c. 5 km NNE of Bordertown (AD); (Loydella): *Conn* 1040, 28.ix.1980, Braendler's scrub (AD); (Wood Hill): *Cleland s.n.*, 12.x.1938, Chauncey's Line (AD 966031506); Northern Calcarene Ridges and Plains (Catana): *J.M. Black* 25, -ix.1917, Yumali (AD); (Karoonda): *E. & A. Ashby* 1028, -xi.1940, between Keith and Bordertown (AD); Murray Lakes (Goolwa): *Carrick* 2980, 11.xi.1971, Finnis (AD).—Mt Lofty Block: Peninsula Uplands (Sandergrrove): *Cleland s.n.*, 26.xi.1966, Sandergrrove scrub (AD 97315375); Kangaroo Island (Mt Marsden): *Crocker s.n.*, 13.xi.1954, Bay of Shoals (ADW 4341); (Amberley): *Conn* 1057-1063, 11.xi.1980, North Coast road, c. 1 km WNW of Playford Highway (AD, MEL); (MacGillivray): *Ising s.n.*, 12.x.1922, MacGillivray (AD 97249325); (Gantheaume): *Crisp* 394, 28.viii.1971, western boundary of Dudley National Park (AD).—[Yorke Peninsula] Gulf Plains (Workurna): *B. Copley* 1408, 29.viii.1967, c. 16 km N of Bute (AD).—[Eyre Peninsula] Northern Myall Plains (Middleback Range): *Lothian & Francis* 706, 18.ix.1960, Middleback ranges (AD); Central Mallee Plains and Dunes (Midgee): *Orchard* 2943, 29.xii.1970, c. 10 km S of Iron Duke (AD); (Cleve): *Lothian s.n.*, 29.vi.1959, 15 km N of Cowell (AD 96322062).

6. *Prostanthera florifera* Conn, *sp. nov.*

Species nova Sectionis Klanderiae. *Frutices* parvi 0.3-1 m. alti. *Rami* et *ramuli* plus minusve teretes, dense tomentosi. *Folia* sparsim tomentosa usque glabrescentia, glandifera; *petiolus* absens; *lamina* linear-ovovata usque anguste oblonga, 4-10 mm. longa, 0.6-1 mm. lata, basi attenuata, margine integro, apice obtuso usque rotundato. *Pedicellus florum* 3-4 mm. longus, sparsim tomentosus usque glabrescens, *prophyllis* usque ad 1 mm. e basi calycis affixis. *Calyx* 7-12 mm. longus, glaber, glandifera; *tubus* 5-7 mm. longus; *lobi* late deltoidei, 2-5 mm. longi, circa 5-7 mm. lati, margine fimbriato, apice rotundato. *Corolla* 20-26 mm. longa, rubra; *tubus* 12-15 mm. longus, extra in partibus distalibus sparsim tomentosus, intra glaber; *lobi* extra sparsim tomentosi, intra glabrescentes, *abaxialis-mediano* oblongo-ovovato, circa 5 mm. longo, 2.5-3 mm. lato, margine plus minusve irregulari, apice obtuso usque rotundato, emarginato, sinu 0.5 mm. longo, *lateralibus* ovatis usque oblongo-ovatis, 3-4 mm. longis, 2-3 mm. latis, margine fimbriato, apice obtuso, *adaxiali-mediano* plus minusve ovato-delloideo, 7-9 mm. longo, 8-9 mm. lato, margine plus minusve irregulari, fimbriato, apice obtuso. *Stamina* circa 11 mm. e basi corollae affixa; filamenta 8-10 mm. longi; antherae 1.5-2 mm. longae, appendice 1-2.5 mm. longa. *Pistillum* 25-28 mm. longum; ovarium circa 1 mm. longum; stylus circa 25 mm. longus; lobis stigmatibus circa 1 mm. longis. *Fructus* coccis 2-2.5 mm. longis.

Holotypus: *Conn* 675, 18.ix.1979, Miccollo Hill, Gawler Ranges (Western Pastoral), northern Eyre Peninsula, South Australia (AD; iso in BRI, CANB, K, MEL, NSW, PERTH).

Small, \pm densely branched shrub, 0.3-1 m high. *Branches* \pm terete, densely tomentose, at least some leaves clustered on short branches. *Leaves* very sparsely hairy, especially medially and basally, to glabrescent, glandular; *petiole* absent; *lamina* linear-obovate to narrowly oblong, 4-10 x 0.6-1 mm [length to width ratio 7.4-11.3, distance of maximum width from base to total lamina length 0.61-0.88], \pm flat, thick; base attenuate; margin entire; apex obtuse to rounded; venation not visible. *Pedicel* 3-4 mm long, sparsely hairy to glabrescent; *prophylls* inserted up to 1 mm from base of calyx, hence overlapping basal part of calyx,



Fig. 64. *Prostanthera florifera*.—A. twig and flowers; B. glands on branch; C. open corolla; D. stamens—ventral and dorsal views; E. open calyx to show mericarps, style and stigma (all Whibley 387).

narrowly oblong to linear-ovate c. 3 mm long, slightly concave, both surfaces glabrous, rarely with an occasional hair; margin sparsely fimbriate; apex obtuse. *Calyx* 7-12 mm long, glabrous, glandular; *tube* 5-7 mm long, 5-6 mm wide at mouth; *lobes* broadly triangular 2-5 mm long, c. 5-7 mm wide at base; margin fimbriate; apex rounded. *Corolla* 20-26 mm long; outer surface of tube pink-red; inner surface pale pink with tinge of white or with pink-red blotches; inner surface of lobes white with dark brown blotches or sometimes yellow-brown with pink spots; *tube* 12-15 mm long; outer surface sparsely tomentose distally; inner surface glabrous, with a few scattered glandular hairs distally; *lobes* sparsely tomentose on outer surface, glabrescent on inner surface; *abaxial median lobe* oblong-obovate, c. 5 mm long, 2.5-3 mm wide at base; margin \pm irregular; apex obtuse to rounded, emarginate; sinus 0.5 mm long; *lateral lobes* ovate to oblong-ovate, 3-4 mm long, 2-3 mm wide at base; margin fimbriate; apex obtuse; *adaxial median lobe-pair* \pm ovate-deltoid, 7-9 mm long, 8-9 mm wide at base; margin \pm irregular, fimbriate, at least basally and distally; apex obtuse. *Stamens* inserted c. 11 mm above base of corolla; filaments 8-10 mm long, glandular with stalked glands and broad triangular glandular trichomes; anthers 1.5-2 mm long; lobes with a minute basal acumen; one side of connective basally extended to form a long slender appendage 1-2.5 mm long, with a few triangular trichomes on appendage. *Pistil* 25-28 mm long; ovary c. 1 mm long, diameter c. 1 mm at base, lobes small, c. 0.5 mm long; style c. 25 mm long; stigma lobes c. 1 mm long. *Mericarps* 2-2.5 mm long, distally 1-1.5 mm extended beyond base of style. Figs 64 & 65.

Distribution: South Australia—Western Pastoral (Gawler and Uno Ranges).

Conservation status: not presently endangered—Risk code = 3V.

Ecology

Occurs on rocky precambrian porphyric (Twidale 1968) rhyodacite derived soils with scattered shrubs of *Acacia sowdenii*, *A. montana*, *Eremophila interstans*, *Melaleuca uncinata*, spinifex (*Triodia*), *Isopogon*, *Calytrix* and ephemerals, especially on hills in rocky places towards ridge tops. Usually occurring at higher altitudes than *Dodonaea viscosa* (Sapindaceae). Soils silty.

Note

This species is closely related to *P. aspalathoides* (refer pp. 305-310) and the relationship between these two is graphically presented in the canonical variate scattergrams and the nearest neighbour phenogram (Figs 7-9 [*P. florifera* = D, *P. aspalathoides* = 1-4]). *P. florifera* is most readily distinguished from the latter species by having longer anther appendages [1-2.5 mm long *cf.* up to 0.3 (-0.5) mm in *P. aspalathoides*]. Several other characters are larger and/or longer in *P. florifera* than *P. aspalathoides*. For example, *P. florifera* tends to have longer pedicels (3-4 mm *cf.* 2-3 mm), longer calyces (7-12 mm *cf.* 5-7 mm [longer calyx tube: 5-7 mm *cf.* 3-4 mm]), longer corolla (20-26 mm *cf.* 10-20 mm [longer corolla tube: 12-15 mm *cf.* 8-11 mm]), longer abaxial median corolla lobe (c. 5 mm *cf.* 2-3 mm), and longer style (c. 25 mm *cf.* 15-20 mm). The collections from the Uno Range tend to have smaller leaves (more typical of *P. aspalathoides*) than those from the Gawler Ranges.

Selected specimens examined (c. 50 collections)

SOUTH AUSTRALIA.—[northern Eyre Peninsula] Western Pastoral (Uno Range): *Donner* 8088, 8095, 23.ix.1981, eastern side of main range, southern end (AD); *Whibley* 7864, 7870, 24.ix.1981, north-western end of range (AD); *Whibley* 7962, 25.ix.1981, c. 10 km E of Uno Station (AD); (Gawler): *Barker* 3583, 24.ix.1978, c. 18 km NNE of Peterby Tank (AD); *Conn* 675, 18.ix.1979, Miccollo Hill (AD); *Conn* 679, 19.ix.1979, Mt Yardea (AD, MEL); *Conn* 680, 19.ix.1979, Kododo Hill (AD, MEL); *B. Copley* 2093, 2095, 31.viii.1968, c. 25 km E of

Yardea homestead (AD); *B. Copley* 2739, 1.viii.1969, c. 9 km W of Yardea homestead (AD); *Crawford s.n.*, 16.x.1968, NE of Buckleboo (AD, ADW); *Donner* 3227, 28.ix.1969, Mt Ive (AD); *Gardiner s.n.*, 5.viii.1969, Spring Hill, c. 90 km NW of Kimba (AD); *Haegi* 732, 17.x.1975, c. 25 km NNW of Kimba (AD); *Haegi* 756, 17.x.1975, c. 50 km NNW of Minnipa (AD); *Haegi* 831, 21.x.1975, Mt Yardea (AD); *Lay* 687, 29.ix.1972, c. 5 km S of Yarna homestead (AD); *Newman s.n.*, -ix.1962, Hiltaba Station (AD); *Orchard* 980 26.vii.1968, Mt Partridge (AD); *Orchard* 1789, 1796, 27.x.1968, c. 40 km N of Minnipa (AD); *Orchard* 2168, 15.viii.1969, SW part of Yandinga Gorge (AD); *Orchard* 2230, 26.ix.1969, Yandinga Gorge (AD); *Orchard* 2329, 28.ix.1969, c. 5 km E of intersection of Yardea, Nonning and Kingoonya roads (AD); *Reichstein* 1581, 28.viii.1973, Nonning Station (AD); *Rohrlach* 422, Peterlumbo (AD); *Rohrlach* 497, 3.ix.1959, E corner of sect. 31, Pinkawillinie (AD); *Rohrlach* 785, 27.viii.1960, c. 2 km NW of Pile Pudla Dam (AD); *Rohrlach* 907, 17.ix.1961, Thurlga Station (AD); *Spooner* 2524, 8.ix.1972, Kododo Hill (AD); *Symon* 8040, 8045 B, 1.x.1972, near summit of Mt Nott (ADW); *Symon* 8173, 5.x.1972, 2 km NW of Dancing Bob Dam (ADW); *Symon* 8175, 5.x.1972, Waltinga Dam (ADW); *Symon* 8189, 6.x.1972, 6 km NW of Pine Lodge (ADW); *Whibley* 387, 15.x.1958, 6 km NW of Minnipa-Yardea road (AD); *Whibley* 797, 27.ix.1960, c. 25 km NNW of Kimba, along Hundred line Gunyarie and Cortlinye (AD); *Wilson* 279, 7.x.1958, 13 km SW of Buckleboo railway Siding (AD); *Wilson* 555, 17.x.1958, Mt Yardea (AD).

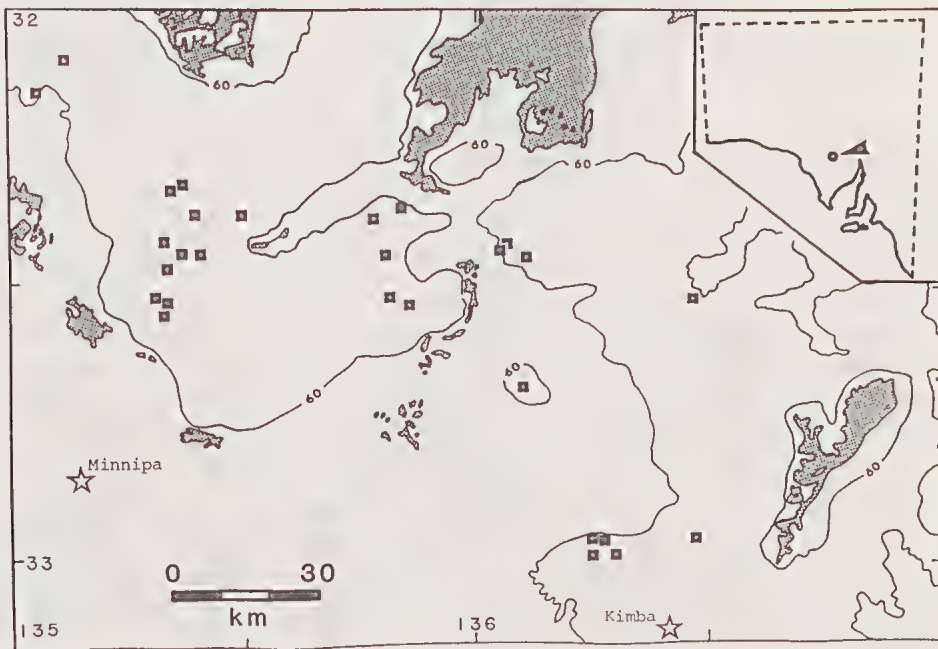


Fig. 65. Distribution map of *Prostanthera florifera*. Stippled areas = lakes or salt pans; contour lines (60 m). Locality of Gawler Ranges and Uno Range given in insert map.

7. *Prostanthera pedicellata* Conn, *sp. nov.*

Species nova Sectionis Klanderiae. *Frutices* parvi 0.3-1 m. alti. *Rami* et *ramuli* teretes usque subteretes, saepe internodiis iuvenibus leviter sulcatis, glabris, dense glandiferis. *Folia* glabra, glandifera; *petiolus* absens aut si praesens tum minus quam 1 mm. longus; *lamina* angusta, ovata, oblonga usque obovata, (3-) 5-8 (-11) mm. longa, 1.5-2.5 mm. lata, basi attenuata, margine integro parum incrassato, saepe parum recurvo, apice obtuso, saepe recurvo. *Pedicellus florum* 8-15 mm. longus, ad basim glaber, alibi sparsim tomentosus, *prophyllis* 1-5 mm. e basi calycis affixis. *Calyx* 6-8 mm. longus, extra tomentosus; *tubus* 4-5 mm. longus, intra glaber; *lobi* plus minusve deltoidei, 2.5-3 mm. longi, 3-4 mm. lati, intra glabri praeter ad marginem sparsim tomentosi, raro glabri, apice obtuso usque subacuto. *Corolla* 20-25 mm. longa, rubra, extra in partibus distalibus tomentosa, saepe dense; *tubus* 11-15 mm. longus; *lobi* intra sparsim pilosi, *abaxiali-mediano* plus minusve ovato, 3-5 mm. longo, circa 2 mm. lato, recto usque recurvo, margine integro, apice subacuto usque obtuso, *lateralibus* plus minusve deltoideis usque ovatis, circa 2 mm. longis, margine integro, *adaxiali-mediano* late oblongo usque subovato, interdum late ovato, 5-6 mm. longo, (6-) 8-10 mm. lato, margine integro, apice rotundato, plerumque emarginato, sinu usque ad 1 mm. longo. *Stamina* circa 10 mm. e basi corolla affixa; filamenta 10-12 mm. longi; antherae 2-2.5 mm. longae, appendice absens aut si praesens tum minus quam 0.1 mm. longa. *Pistillum* 25-30 mm. longum; ovarium circa 0.6 mm. longum; stylus 20-25 mm. longus; lobis stigmatibus usque ad 0.5 mm. longis. *Fructus* coccis 2-3 mm. longis.

Holotypus: Ashby 2993, 3.ix.1969, Pindar, northern Avon (South-West), Western Australia (AD; iso in PERTH).

Small slightly spreading shrub, 0.3-1 m high. Branches terete to subterete, often with faint grooving on distal internodes (from one leaf axis to next node alternately), glabrous, densely glandular; glands \pm hemispherical, touching. *Leaves* arranged along branches, not clustered, glabrous, glandular, (2-) 17-87 glands/mm²; petiole absent or if present then less than 1 mm long, usually indistinct, grooved on adaxial surface; *lamina* narrow, ovate, oblong to obovate, (3-) 5-8 (-11) x 1.5-2.5 mm [lamina length to width ratio 4.6-6.7, distance of maximum width from base of lamina to total lamina length 0.26-0.67]; base attenuate; margin entire, slightly thickened, often slightly recurved; apex obtuse, often recurved; venation indistinct, occasionally base of midrib faintly raised on lower surface. *Pedicel* 8-15 mm long, glabrous basally, sparsely hairy distally, especially above point of insertion of prophylls; *prophylls* inserted 1-5 mm from distal end of pedicel, usually not overlapping basal part of calyx, narrowly oblong to linear-obovate, 2.5-4 x 0.5 mm, slightly concave, glabrous or sparsely hairy; apex obtuse, often slightly recurved. *Calyx* 6-8 mm long, green with maroon tinge distally; outer surface hairy; hairs 0.4-0.6 mm long, white; *tube* 4-5 mm long; inner surface glabrous; *lobes* \pm triangular, 2.5-3 mm long, 3-4 mm wide at base; inner surface glabrous basally, sparsely hairy towards margin (rarely glabrous); apex obtuse to subacute. *Corolla* 20-25 mm long, red; outer surface distally hairy, often densely so; *tube* 11-15 mm long; *lobes* sparsely pilose on inner surface; *abaxial median lobe* \pm ovate, 3-5 mm long, c. 2 mm wide at base, straight to recurved; margin entire; apex subacute to obtuse; *lateral lobes* \pm triangular to ovate, c. 2 mm long; margin entire; *adaxial median lobe-pair* broad-oblong to subobovate, sometimes broad-ovate, 5-6 mm long, (6-) 8-10 mm wide at base; margin entire; apex rounded, usually emarginate; sinus up to 1 mm long. *Stamens* inserted c. 10 mm above base of corolla; filaments 10-12 mm long, with a few scattered, minute \pm triangular glandular trichomes; anthers 2-2.5 mm long; base of lobes with small acumen 0.1-0.3 mm long; appendage absent or if present then less than 0.1 mm long. *Pistil* 25-30 mm long; ovary c. 0.6 (-1) mm long, diameter at base c. 1 mm; lobes small, c. 0.3 mm long; style 20-28 mm long; stigma lobes up to 0.5 mm long. *Mericarps* 2-3 mm long, distally c. 1 mm extended beyond base of style; seed unknown. Figs 66 & 68.

Distribution: Western Australia (South-West: Avon).

Conservation status

This species appears to be very rare and the small population at Pindar (Western Australia) is apparently rapidly decreasing in size as its habitat is cleared—Risk Code = 1E.

Ecology

Growing in *Acacia*, *Eremophila*, *Melaleuca* shrubland. Soil a yellow-brown loam with ironstone gravel often present on the surface.



Fig. 66. *Prostanthera pedicellata*.—Twig and flowers (Ashby 2993).

Note

This new species has its closest affinities with *P. semiteres*. In particular, there is a superficial similarity between *P. pedicellata* and *P. semiteres* ssp. *intricata*. Both have relatively long pedicels and both lack staminal appendages. *P. pedicellata* differs by having calyces with hairy outer surfaces (glabrous in *P. semiteres*) and broader usually longer leaves (leaves 1.5-2.5 mm wide in *P. pedicellata*, 0.5-1.2 mm wide in *P. semiteres*).

Short 994 (AD), which was collected towards the end of a relatively dry season (15.xi.1979), has leaves similar to *P. semiteres* and so may represent an intermediate specimen between the two taxa. *Ross 2734 & 2735* (MEL) have calyces which are glabrous on their inner surfaces and only have a few scattered hairs on their outer surfaces. In all other respects, these collections are identical with *Ross 2732, 2733, 2736 & 2737* which are all from the same population.

Specimens examined

WESTERN AUSTRALIA.—South-West: northern Avon (Pindar): *Ashby 2993*, 3.ix.1969 (AD, PERTH); *Ashby 5035*, -ix.1973 (AD); *Ashby 5112*, -ix.1973 (AD); *Maiden s.n.*, -x.1909 (NSW 126722, NSW 126726); *Oliver for Ashby 3931*, -viii.1971 (AD); *Phillips 54467*, 20.ix.1968 (AD); *Ross 2732-2737*, 1.ix.1982 (MEL); *Short 994*, 15.xi.1979 (AD).

8. *Prostanthera incurvata* Conn, sp. nov.

Species nova Sectionis Klanderiae. *Frutices* parvi, 0.4-0.7 m. alti. *Rami* et *ramuli* plus minusve teretes, tomentosi, glandiferi. *Folia* glabra; *petiolus* absens aut si praesens tum minus quam 1 mm. longus; *lamina* complanata angusta, obovata usque oblonga, 5-10.3 mm. longa, 0.8-1.2 mm. lata, saepe incurvata, basi attenuata, margine integro, apice obtuso usque rotundato. *Pedicellus florum* 0.8-1.8 mm. longus, glaber, dense glandifer, *prophyllis* ad basim calycis affixis. *Calyx* 6-8 mm. longus, extra glaber, intra ad basim glaber, alibi dense tomentosus; *tubus* 4-5 mm. longus; *lobi* late deltoidei, (1.5-) 2 mm. longi, 3.5-4 mm. lati, margine integro, apice obtuso. *Corolla* 15-20 mm. longa, rosea usque rubra, interdum lutea, extra in partibus distalibus moderate usque dense tomentosa, intra glabra usque glabrata; *tubus* circa 10 mm. longus; *lobus abaxiali-medianus* plus minusve obovatus, 3-3.5 mm. longus, rectus usque recurvus, margine integro, apice obtuso, *lateralibus* oblongo-ovatis, 2-2.5 mm. longis, margine integro, apice obtuso usque rotundato, *adaxiali-mediano* plus minusve obovato, circa 3 mm. longo, recto, margine integro usque parum irregulari, apice obtuso, emarginato, sinu 1-1.5 mm. longo. *Stamina* 7-8 mm. e basi corollae affixa; filamenta 6-7 mm. longa; antherae 1.5-1.8 mm. longae, appendice absenti. *Pistillum* 20-23 mm. longum; ovarium 0.6-0.8 mm. longum; stylus 18-20 mm. longus; lobis stipitatis circa 1 mm. longis. *Fructus* coccis circa 2 mm. longis.

Holotypus: *N.T. Burbidge 2664*, 19.ix.1947, Pioneer rock, N of Lake Cowan, Western Australia (PERTH, iso in CANB).

Small shrub, 0.4-0.7 m high. *Branches* ± terete, hairy (rarely glabrous); hairs usually ± restricted to two opposite longitudinal grooves, 80-190 (-270) hairs/mm², 0.09-0.3 mm long, ± erect [base of hair to first bend 0.04-0.07; greatest distance hair from branch is 0.04-0.16 mm], white, moderately dense-glandular, 56-109 glands/mm²; glands hemispherical. *Leaves* usually clustered on short lateral shoots, sometimes arranged along the branches, glabrous; *petiole* absent or if present then less than 1 mm long; *lamina* flattened, narrow, obovate to oblong, 5-10.3 x 0.8-1.2 mm [length to width ratio 4.9-14; distance of maximum width from base of lamina to total lamina length 0.2-0.8], frequently incurved; base attenuate; margin entire; apex obtuse to rounded; venation indistinct; midrib region often slightly sunken on adaxial surface. *Pedicel* 0.8-1.5 (-2) mm long, ± terete, light green, glabrous, densely glandular; *prophylls* inserted at base of calyx (rarely up to 0.3 mm from base of calyx), hence overlapping with base of calyx, ± narrowly ovate, 1.7-4.2 (-4.7) x c. 0.6 mm [length to width ratio 3.4-7 (-8.4)], glabrous; margin entire; apex obtuse to subacute. *Calyx* 6-8 mm long, green; outer surface glabrous, moderately to densely glandular; glands hemispherical, 40-133 glands/mm²; inner surface glabrous basally, densely hairy (indumentum tomentose to pubescent) in mouth and on lobes, (51-) 100-c. 400 hairs/mm²; hairs weak, ± curled, entangled, usually less than 0.08 mm long,



Fig. 67. *Prostanthera incurvata*.—Twig and flowers (Phillips CBG 23260).

white; *tube* 4-5 mm long; *lobes* broadly triangular, (1.5-) 2 mm long, 3.5-4 mm wide at base [calyx lobe to tube ratio 0.5-0.8]; margin entire; apex obtuse. *Corolla* 15-20 mm long, pink to red, sometimes yellow; outers surface moderately to densely hairy distally (70-100 hairs/mm²); hairs 0.3-0.4 mm long, white; inner surface glabrous, sometimes with an occasional hair near margin; *tube*; c. 10 mm long; *abaxial median lobe* \pm obovate, 3-3.5 mm long, extended forward to recurved; margin entire; apex obtuse; *lateral lobes* oblong-ovate, 2-2.5 mm long; margin entire; apex obtuse to rounded; *adaxial median lobe-pair* \pm obovate, c. 3 mm long, extended forward; margin entire to slightly irregular; apex obtuse, emarginate; sinus 1-1.5 mm long. *Stamens* inserted 7-8 mm from base of corolla; filaments 6-7 mm long, glandular triangular trichomes present; anthers 1.5-1.8 mm long; base of lobes with minute acumen c. 0.1 mm long; appendage absent. *Pistil* 20-23 mm long; ovary 0.6-0.8 mm long, lobes small, c. 0.1 mm long; style 18-20 mm long; stigma lobes c. 1 mm long. *Mericarps* c. 2 mm long (possibly immature), distally extended c. 0.8 mm beyond base of style. Figs 67 & 68.

Distribution: Western Australia (Eremaean: Austin, Coolgardie).

Conservation status: The conservation status of this species is not known—Risk code = 3K.

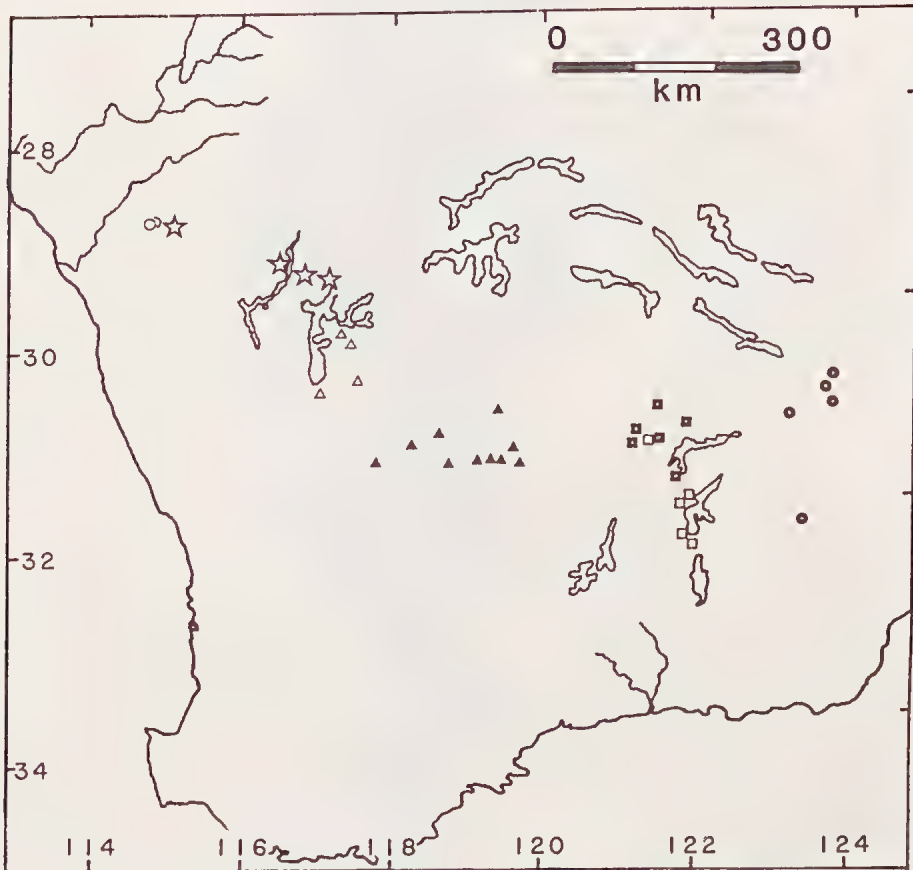


Fig. 68. Distribution map of the *Prostanthera laricoides* complex. • *P. laricoides*; ■ *P. incurvata*; □ *P. incurvata* (hairy branches); ▲ *P. semiteres* ssp. *semiteres*; △ *P. semiteres* ssp. *intricata*; ☆ *P. patens*; ○ *P. pedicellata*.

Ecology

Only three collectors have made notes on the ecology of this species. Near Londonderry it occurs as rare shrub in *Eucalyptus longicornis* open low woodlands on a moderately exposed stony greenstone ridge in well-drained stony loam soil (Newbey 6123). At Mount Hunt it occurs on serpentinites (Bale 123), whereas at Lake Cowan it occurs in red sands (Broadbent 1054).

Note

This new species is closely related to *P. semiteres*. However, *P. incurvata* has a shorter pedicel [0.8-1.5 (-2) mm cf. 3-15 mm in *P. semiteres*], smaller usually incurved leaves, a larger lamina length to width ratio, is more glandular and hairier than *P. semiteres*. However, Cronin s.n. (MEL 1512008) is glabrous. For further discussion on this species refer 'Numerical analysis of the *Prostanthera laricoides* complex' and 'Morphological variation in the *Prostanthera laricoides* complex':

Specimens examined

WESTERN AUSTRALIA.—Eremaean: Austin: Bale 123, -x.1965, Mt Hunt, near Boulder (PERTH).—Coolgardie: Beard 3371, 26.v.1964, S of Coolgardie (KP); Blackall 979, -x.1931, 25 miles N of Norseman (PERTH); Broadbent 1054, 23.vii.1953, Lake Cowan (NSW); N. Burbidge 2664, 19.ix.1947, Pioneer Rock, near Lake Cowan (CANB); Canning CBG 26146, 6.ix.1968, 22 miles from Coolgardie, towards Norseman (AD 96920342); Chinnock 3055, 15.ix.1976, Mt Monger (AD); Cronin s.n., anno 1893, between upper Blackwood River and Lake Lefroy (MEL 1512008); Helms s.n., -vi.1898, Coolgardie (NSW 126727); Helms s.n., -vii.1899, Coolgardie (K, PERTH); Kemsley s.n., -v.1952, Kambalda (MEL 43820); Lidgey 5 & 7, 22.viii.1900, Hampton plains, near Coolgardie (K); Newbey 6123, 28.ix.1979, 13 km W of Londonderry (PERTH); Phillips CBG 20619, 11.ix.1962, c. 75 miles N of Norseman (AD 96915102); Phillips CBG 23260, 4.ix.1968, Spargoville (AD 96918133); Phillips CBG 23274, 4.ix.1968, ?Beacon Hill, Norseman (AD 96918148); Wilson 3112, 14.ix.1964, near Londonderry (AD).

9. *Prostanthera semiteres* Conn, sp. nov.

Species nova Sectionis Klanderiae. *Fruites* parvi, usque ad 1.4 m. alti. *Rami* et *ramuli* plus minusve teretes, glabri. *Folia* glabra; *petiolus* absens aut si praesens tum usque ad 0.3 mm. longus; *lamina* angusta, obovata usque oblonga, 2-12 mm. longa, 0.5-1.1 mm. lata, basi attenuata, margine integro, apice obtuso. *Pedicellus florum* 3-15 mm. longus, glaber, *prophyllis* usque ad 2.5 mm. e basi calycis affixis. *Calyx* 5-7.3 mm. longus, extra plerumque glaber; *tubus* 4-6 mm. longus, intra glaber vel tomentosus; *lobi* transverse angusto-deltoides, 0.5-2 mm. longi, 3-5 mm. lati, intra in partibus distalibus tomentosi, margine integro, apice obtuso. *Corolla* 16-25 mm. longa, rubra vel rosea, extra in partibus distalibus tomentosus; *tubus* 6-14 mm. longus; *lobus abaxiali-medianus* plus minusve obovatus, oblongo-ovatus usque deltoideus, 2-3.5 mm. longus, recurvus usque reflexus, margine integro, apice obtuso usque rotundato, *lateralibus* oblongis, vel latis et ovatis usque deltoideis, 1-3 mm. longis, erectis usque recurvis, margine integro, apice subacuto usque obtuso, *adaxiali-mediano* lato, ovato usque obovato, 3-5 mm. longo, margine integro, apice obtuso, emarginato, sinu usque ad 1.5 mm. longo. *Stamina* 7.5-9 mm. e basi corollae affixa; filamenta 4-8 mm. longa; antherae 1.2-2 mm. longae, appendice absenti. *Pistillum* 22-27 mm. longum; ovarium 0.5-0.8 mm. longum; stylus 21-25 mm. longus; lobis stigmatibus 0.1-0.7 mm. longis. *Fructus* coccis 2-3 mm. longis.

Holotypus: Chinnock 3132, 20.ix.1976, 2.9 km E of Campion, on Warralakin road, South-West botanical district, Western Australia (AD).

Small shrub, up to 1.4 m high. *Branches* ± terete, glabrous. *Leaves* arranged along main axes and branches, not clustered along short axes, glabrous; *petiole* absent or if present, then up to 0.3 mm long; *lamina* narrow, obovate to oblong, 2-12 x 0.5-1.2 mm; base attenuate; margin entire; apex obtuse; venation indistinct; midrib usually slightly sunken on adaxial surface. *Pedicel* 3-15 mm long, glabrous; *prophylls* inserted up to 3 mm from base of calyx, narrow, oblong to obovate, 1.5-3 (-4.1) x 0.2-0.5 mm [length to width ratio 3.5-8.7], often incurved, becoming recurved to reflexed, glabrous; margin entire; apex obtuse. *Calyx* 5-7.3 mm long; outer surface usually glabrous, glandular; *tube* 4-6 mm long; inner surface glabrous or hairy distally; *lobes* transversely narrow-triangular, 0.5-2 mm long, 3-5 mm wide at base, glabrous at base, hairy distally; margin entire; apex



Fig. 69. *Prostanthera semiteres* ssp. *intricata*.—Twig and flowers (Ashby 3585).

obtuse. *Corolla* 16-25 mm long, red or pink; outer surface hairy distally, 35-48 hairs/mm²; *tube* 6-14 mm long; inner surface glabrous; *abaxial median lobe* \pm obovate, oblong-ovate to triangular, 2-3.5 mm long, recurved to reflexed; margin entire; apex obtuse to rounded; *lateral lobes* oblong, or ovate to triangular, 1-3 mm long, erect to recurved; margin entire; apex subacute to obtuse; *adaxial median lobe-pair* broad, ovate to obovate, 3-5 mm long; margin entire; apex obtuse, emarginate; sinus up to 1.5 mm long. *Stamens* inserted 7.5-9 mm from base of corolla; filaments 4-8 mm long; anthers 1.2-2 mm long; base of lobes with a minute acumen up to 0.2 mm long; appendage absent. *Pistil* 22-27 mm long; ovary 0.5-0.8 mm long, diameter up to 1.2 mm at base, lobes small, 0.1-0.2 mm long; style 21-25 mm long; stigma lobes 0.1-0.7 mm long. Mericarps 2-3 mm long, distally 1-1.7 mm extended beyond base of style. Figs 68 & 69.

Distribution

Western Australia (Eremaean: Austin, Coolgardie; South-West: Avon).

Conservation status: Considered not at risk.

Note

This species has its closest affinities with *P. pedicellata* (refer p. 316 for details). It is also closely related to *P. incurvata*. However, it is readily distinguishable from the latter species by its longer pedicels [3-15 mm long cf. 0.8-1.5 (-2) mm in *P. incurvata*], usually larger leaves and smaller lamina length to width ratio. For further discussion of this species refer 'Numerical analysis of the *Prostanthera laricoides* complex' and 'Morphological variation in the *Prostanthera laricoides* complex'.

The north-western populations of *P. semiteres* (Fig. 68) have noticeably longer pedicels and smaller leaves than the more south-eastern ones. The former group is recognized as a distinct subspecies (*viz.* *P. semiteres* ssp. *intricata*). The key differences between the two subspecies are summarized below.

Key to subspecies

- 1a. Pedicel up to 5.5 mm long; prophylls inserted up to 1 mm from base of calyx; leaves (5.5-) 9-11 mm long; calyx lobes to calyx tube ratio 0.14-0.43 9.1 ssp. *semiteres*
- 1b. Pedicel 7-15 mm long; prophylls inserted (1.5-) 2-3 mm from base of calyx; leaves 2-6 mm long; calyx lobes to calyx tube ratio 0.3-0.56 9.2 ssp. *intricata*

9.1 ssp. *semiteres*

Small shrubs, up to 1.4 m high. *Lamina* narrow, obovate to oblong, 8-12 x 0.7-1.1 mm [length to width ratio 8-17 (-20); ratio of distance of maximum width from base to total lamina length (0.05-) 0.4-0.8]. *Pedicel* 3-4 (-5.5) mm long, green, often with purple tinge; *prophylls* inserted up to 1 mm from base of calyx. *Calyx* green or purple-green; outer surface glabrous, glandular, (17-) 22.5-65 (-83.3) glands/mm²; *tube* glabrous; *lobes* 0.5-1.5 mm long, c. 5 mm wide at base [calyx lobe to tube ratio 0.14-0.43]; inner surface hairy distally, (3-) 41-147 (-253) hairs/mm². *Corolla tube* 6-12 mm long. *Staminal filaments* 4-6.5 mm long. *Stigma lobes* 0.1-0.4 mm long. Fig. 68.

Distribution: refer Fig. 68.

Ecology

Occurs amongst granitic rocks (*Beard* 4744, 5944), in granitic sandy loams (*Chinnock* 3132), on schistose hills (*Gardner* 2797), and in red clay-loams (*George* 2670).

Specimens examined

WESTERN AUSTRALIA.—Eremaean: Coolgardie: *Anon s.n.*, 21.x.1895, Southern Cross (PERTH); *Beard 4744*, 17.vii.1967, 20 miles W of Bullfinch (A, PERTH); *Beard 5091*, -viii.1967, Warralackin-Bullfinch area (KP); *Beard 5944*, 19.vii.1970, 6 miles N of Weowanie Rock (KP, PERTH); *Blackall 896*, 13.xi.1931, by salt lake at Southern Cross (PERTH); *Demarz 5261*, 10.x.1974, 4 miles N of 242 mile peg on Great Eastern Highway (KP, PERTH); *Gardner 2797*, -ix.1931, Lake Polaris, Southern Cross (K, PERTH); *George 2670*, 20.viii.1961, c. 28 miles E of Southern Cross (PERTH); *Newbey 2538*, 5.ix.1966, Koolyanobbing Range (PERTH); *Newbey 5712*, 20.vii.1979, 0.5 km N of Southern Cross (PERTH); *P. Wilson 3508*, 23.ix.1964, 9 km E of Southern Cross (AD); *P. Wilson 3515*, 23.ix.1964, 16 km E of Southern Cross (AD).—South-West: Avon: *Chinmock 3132*, 20.ix.1976, 2.9 km E of Campion (AD); *Gardner 2060*, 6.x.1927, Noongar (K, PERTH).

9.2 ssp. intricata Conn, ssp. nov.

Frutices parvi, circa 0.3 m. alti. *Lamina* angusta, oblonga usque obovata, 2-6 mm. longa. *Pedicellus florum* 7-15 mm. longus, *prophyllis* 2-2.5 mm. e basi calycis affixis. *Lobis calycis* 1-2 mm. longi, circa 3 mm. lati. *Tubus corollae* 9-14 mm. longus. *Filamenta staminum* 6-8 mm. longa. *Lobi stigmatis* 0.5-0.7 mm. longi.

Holotypus: *Ashby 3585*, 7.ix.1970, Beacon, South-West botanical district, Western Australia (PERTH; iso in AD).

Small shrub, c. 0.3 m high. *Lamina* narrow, oblong to obovate, 2-6 x 0.5-1 mm [length to width ratio 5-9.6; ratio of distance of maximum width from base to total lamina length up to 0.66]. *Pedicel* 7-15 mm long, maroon or dark green with tinge of red; *prophylls* inserted (1.5-) 2-3 mm from base of calyx. *Calyx* green, often dark green and/or with tinge of maroon distally; outer surface glabrous or rarely with an occasional hair distally, 0 (-3) hairs/mm², moderately glandular 20-46 glands/mm²; inner surface moderately to densely hairy, 34-106 hairs/mm²; *lobes* 1-2 mm long, c. 3 mm wide at base [calyx lobe to tube ratio 0.3-0.56]. *Corolla tube* 9-14 mm long. *Staminal filaments* 6-8 mm long. *Stigma lobes* 0.5-0.7 mm long. Figs 68 & 69.

Distribution: refer to Fig. 68.

Ecology: not known.

Note

This subspecies is easily distinguished from *ssp. semiteres* by its long pedicels [7-15 mm long *cf.* up to 5.5 mm in *ssp. semiteres*] and short leaves [2-6 mm long *cf.* (5.5-) 9-11 mm in *ssp. semiteres*]. It is superficially similar to *P. pedicellata*, however the usually glabrous outer surface of the calyx, the densely hair inner surface of the calyx, and the small calyx lobe to tube ratio readily distinguish this subspecies from the latter species.

Specimens examined

WESTERN AUSTRALIA.—Eremaean: Austin: *Weber 5188*, 18.x.1975, c. 15 km E of Mouroubra Homestead (AD).—Coolgardie: Mt Churchman: *Blackall 3432, 3452*, 13.x.1937 (PERTH); *Rosier 309*, 17.ix.1963 (PERTH); *Young s.n., s. dat.* (MEL 43397).—South-West: Avon: *Ashby 3585*, 7.ix.1970, Beacon (AD, PERTH); *Harvey & Rosier 251*, -x.1960, Mollerin (PERTH).

10. Prostanthera laricoides Conn, sp. nov.

Species nova Sectionis Klanderiae. *Frutices parvi*, 0.6-1.2 m. alti. *Rami* et *ramuli* plus minusve teretes, partim dense tomentosi, pilis 0.1-0.2 mm. longis, dense glandiferi, internodiis iuvenibus parum complanatis. *Folia* glabra, dense glandifera; *petiolus* absens; *lamina* teretes, interdum pagina adaxiali leviter sulcata, (5-) 10-18 (-20) mm. longae, 0.4-0.7 mm. latae, basi attenuata, margine integro, apice obtuso usque rotundato. *Pedicellus florum* circa 1 mm. longus, dense tomentosus, *prophyllis* ad basim calycis affixis, mox caducis. *Calyx* 4-6 mm. longus, extra parum tomentosus, pilis usque ad 0.1 mm. longis, intra ad basim glaber, alibi parum tomentosus, pilis (0.07-) 0.1-0.2 mm. longis; *tubus* 3-4.5 mm. longus; *lobi* late deltoidei, 1.5-2 mm, longi, circa 3 mm. lati,



Fig. 70. *Prostanthera laricoides*.—A. twig and flowers; B. flower; C. stamen—ventral view (all Boswell F66)

margine, integro, fimbriato, apice rotundato. *Corolla* 14-18 mm. longa, rubra, extra in partibus distalibus sparsim tomentosa; *tubus* 10-12 mm. longus; *lobus abaxiali-medianus* plus minusve oblongo-ovatus, 3-4 mm. longus, 1.5-2.3 mm. latus, margine integro, fimbriato, apice obtuso usque rotundato, *lateralibus* plus minusve late oblongis usque ovatis, circa 2 mm. longis, circa 2 mm. latis, margine integro, fimbriato, apice rotundato, *adaxiali-mediano* late ovato, circa 4 mm. longo, circa 5 mm. lato, margine integro usque parum irregulari, apice plus minusve obtuso, emarginato, sinu usque ad 1 mm. longo. *Stamina* 8.5-10 mm. e basi corollae affixis; filamenta 4-5 mm. longa; antherae 1.5-1.8 mm. longae, appendice (1-) 1.5-2 mm. longa. *Pistillum* 20-22 mm. longum; ovarium 0.5-1 mm. longum; stylus circa 20 mm. longus; lobis stigmatibus circa 0.5 mm. longis. *Fructus* coccis 2-2.5 mm. longis.

Holotypus: Boswell F66, anno 1967, Cundeelee, Helms botanical district, Western Australia (PERTH).

Small shrub, 0.6-1.2 m high. *Branches* \pm terete, slightly flattened distally, densely tomentose from within each axil to the next upper node; hairs 0.1-0.2 mm long, densely glandular. *Leaves* clustered (leaf bearing branches 1-4 mm long), glabrous, densely glandular; *petiole* absent; *lamina* terete, sometimes faintly grooved along adaxial surface, (5-) 10-18 (-20) \times 0.4-0.7 mm [length to width ratio (12.5-) 17.5-28.5 (-31.25), distance of maximum width from base to total lamina length 0.05-0.86]; base attenuate; margin entire; apex obtuse to rounded; venation not visible. *Pedicel* c. 1 mm long, densely hairy; hairs less than 0.1 mm long, glandular; *prophylls* inserted near distal end of pedicel and so, overlapping basal part of calyx, soon caduous, \pm linear, c. 0.5 mm long, concave, glabrous; margin fimbriate; hairs up to 0.2 mm long; apex obtuse. *Calyx* 4-6 mm long; outer surface sparsely minute-hairy, 45-159 hairs/mm²; hairs up to 0.05-0.1 mm long; inner surface glabrous on basal 2-2.5 mm, sparsely hairy distally, 68-220 hairs/mm², hairs (0.7-) 0.1-0.2 mm long; *tube* 3-4.5 mm long; *lobes* broadly triangular, 1.5-2 mm long, c. 3 mm wide at base; margin entire, fimbriate with hairs c. 0.1 mm long; apex rounded. *Corolla* 14-18 mm long, dull light red; outer surface sparsely tomentose distally; hairs up to 0.2 mm long; *tube* 10-12 mm long; *lobes* glabrous on inner surface; *abaxial median lobe* \pm oblong-ovate, 3-4 \times 1.5-2.3 mm; margin entire, fimbriate; apex obtuse to rounded; *lateral lobes* \pm broad-oblong to ovate, c. 2 mm long, c. 2 mm wide at base; margin entire, fimbriate; apex rounded; *adaxial median lobe-pair* broad-ovate, c. 4 mm long, c. 5 mm wide at base; margin entire to slightly irregular, fimbriate; apex \pm obtuse, emarginate; sinus up to 1 mm long, up to 2 mm wide distally. *Stamens* inserted 8.5-10 mm above base of corolla; filaments 4-5 mm long, with slightly raised glands; anthers 1.5-8 mm long; one side of connective extended to form a basal appendage (1-) 1.5-2 mm long, broad-triangular trichomes present at distal end of appendage, trichomes c. 0.1 mm long. *Pistil* 20-22 mm long; ovary 0.5-1 mm long, diameter c. 0.5 mm at base, lobes small; style c. 20 mm long; stigma lobes c. 0.5 mm long. *Mericarps* 2-2.5 mm long, distally 1 mm extended beyond base of style. Figs 68 & 70.

Distribution: Western Australia (Eremaean: Helms, Coolgardie).

Conservation status: Considered not at risk.

Ecology

All that is known about the ecology of this species is that it occurs 'on sandy soil among rocks' (Royce 5371) near Coonana and on 'moderately exposed sheet deposits of granitic loam to sandy soil on exposed granite bedrock' (Newbey 7033) near Sinclair Soak.

Note

The affinities of *P. laricoides* are uncertain. It is similar to *P. patens* in a number of features (e.g. long anther appendages, prophylls inserted near distal end of pedicel, high density of hairs on outer surface of calyx [refer 'Morphological variation in the *Prostanthera laricoides* complex']), but it has long narrow leaves, and indumentum in two rows on opposite 'sides' of branches (similar to *P. incurvata*). Furthermore, the density of glands on all parts, and the lamina length to width ratio are similar to those of *P. incurvata*.

Overall, *P. laricoides* is probably most closely related to *P. incurvata*. For further discussion of this species refer 'Numerical analysis of the *Prostanthera laricoides* complex' and 'Morphological variation in the *Prostanthera laricoides* complex'.

Specimens examined

WESTERN AUSTRALIA.—Helms: *Boswell F66*, anno 1967, Cundeelee (PERTH); *Butler s.n.*, 26.i.1959, Queen Victoria Springs (PERTH); *Carrick 3995A*, 8 miles S of Cundeelee, 10 miles N of Zanthus (AD); Coolgardie: *Main s.n.*, 9.xii.1953, Newman Rock (PERTH); *Newbey 7033*, 11.viii.1980, 23 km SE Sinclair Soak (PERTH); *Royce 5371*, 29.i.1956, W of Coonana, on Trans. Line (PERTH); *Royce 5472*, 1.x.1956, 15 miles N of Zanthus, towards Cundeelee (PERTH).

11. *Prostanthera ringens* Benth., in Mitch., J. trop. Austral. (1848) 363; in DC., Prodr. 12 (1848) 700; Fl. austral. 5 (1870) 106; Woolls, Pl. New S. Wales (1885) 83; Tate, Trans. & Proc. Roy. Soc. S. Austral. (1889) 111; Handb. fl. extratrop. S. Austral. (1890) 151, 252; C. Moore, Handb. fl. New S. Wales (1893) 352; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4: 3a (1895) 220; F.M. Bailey, Queensl. fl. 4 (1901) 1203, 1204; Dixon, Pl. New S. Wales (1906) 232; F.M. Bailey, Compr. cat. Queensl. pl. (1913) 392; Althofer, Cradle of Incense (1978) 92, 99, 129.

Syntypes: [*Drysdale* (Mitchell 1848, p. 359) for] *T.L. Mitchell 577 & 570* [two numbers but only one specimen], 1 & 16.ix.1846, 'Camp 29. Subtropical New Holland' ['on the Maranoa' [river], Bentham (1870)], Queensland (K n.v.; NSW 126717). [Refer Notes].

P. leichhardtii Benth., Fl. austral. 5 (1870) 106; Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4: 3a (1895) 220; F.M. Bailey, Queensl. fl. 4 (1901) 1203; Compr. cat. Queensl. pl. (1913) 392; Althofer, Cradel of Incense (1978) 31, 124, 125-129.

Syntypes: *Leichhart s.n.*, -viii-ix.- [24.x.1844 (interpolated from diary of Leichhardt 1847)], 'The Sandstone Ranges of Bottletree Creek, lat. 26°30' [long. c. 150°47'E (interpolated from maps of Leichhardt 1847)]', Queensland (K n.v., MEL 43332).

P. lepidota C.T. White, Proc. Roy. Soc. Queensl. 4 (1944) 74; Althofer, Cradle of Incense (1978) 99, 124, 127.

Lectotype (here chosen): *C.T. White 12404*, 13.xi.1943, Enniskillen, Mitchell District, Queensland (BRI 010664 —lower centre; islecto. A, AD, BRI 010664 [excl. lectotype], BRI 010665, CANB, K n.v., MO, NY, UC).

Bushy shrub up to 2 m high, diameter 1-1.5 m. *Branches* quadrangular, with two pairs of lateral ridges, sparsely to moderately hairy between the ridges from within the leaf axis to the next node, nodes hairy; hairs c. 0.1 mm long, densely glandular; glands hemispherical. *Leaves* glabrous or with a few scattered hairs basally; *petiole* absent or if present then up to 2 (-3) mm long; *lamina* oblong, ovate to obovate, often narrow, 6-15 x (1-) 2-6 mm, ± flat; base ± cuneate; margin entire; apex obtuse, often slightly emarginate when lamina ovate or obovate; venation not visible, occasionally faint; midrib slightly raised on abaxial surface, slightly sunken on adaxial surface, or indistinct. *Pedicel* 1-3.5 mm long, hairy; hairs 0.06-0.1 mm long; *prophylls* inserted near base of pedicel, hence not, or just overlapping base of calyx, broad-oblong, 0.6-c. 1 x c. 0.5 mm, concave; abaxial surface shortly pubescent; adaxial surface glabrous; margin fimbriate; apex obtuse. *Calyx* 6-8 mm long (usually at least 10 mm in fruit); outer surface glabrous; inner surface with a few scattered glandular hairs; margin, and occasionally lobes, minutely fimbriate, especially in bud; *tube* c. 5 mm long; *lobes* broadly triangular, c. 2 mm long, c. 3 mm wide at base; margin entire; apex ± rounded. *Corolla* 14-23 mm long, pale blue-light green (olivaceous), light green-yellow or yellow; *tube* c. 10 mm long, diameter at mouth c. 5 mm; outer surface glabrous basally, at least on that portion enclosed by the calyx, distally sparsely hairy; *lobes* hairy on outer surface; inner surface glabrous; *abaxial median lobe* ± ovate to obovate, (3-) 4-5 mm long, c. 4 mm wide; margin entire, slightly irregular; apex obtuse to rounded; *lateral lobes* ovate-oblong, 2-3 mm long, c. 2 mm wide at base; margin irregular; apex obtuse; *adaxial median lobe-pair* ± ovate, 4-9 mm long, 4-6 mm wide at base;



Fig. 71. *Prostanthera ringens*.—A. twig and flowers (*Althofer s.n.*, cultivated material, Burrendong Arboretum); B. twig and flowers (*N. Burbidge 6610*); C. open corolla; D. stamens—ventral and dorsal views; E. part of calyx removed to reveal mericarps (C-D all *Althofer s.n.*).

margin entire to irregular, fimbriate; apex obtuse, sometimes emarginate; sinus up to c. 1 mm long. *Stamens* inserted c. 4 mm from base of corolla; filaments c. 6 mm long, glabrous with a few glandular trichomes; anthers 1.5-2 mm long; base of lobes obtuse, often with a short broad acumen c. 0.1 mm long; appendage absent. *Pistil* 20-25 mm long; ovary 1-1.5 mm long, diameter c. 1 mm at base, lobes small, c. 0.1 mm long; style c. 18 mm long; stigma lobes c. 1 mm long. *Mericarps* 2-2.5 mm long, distally extended c. 1 mm beyond base of style. Figs 71 & 72.

Distribution

Queensland (?Wide Bay or Moreton, Darling Downs, Maranoa, Mitchell), New South Wales (North Western Slopes, Central Western Slopes, North Western Plains, North Far Western Plains).

Conservation status: Considered not at risk.

Ecology

Occurs in rocky sandstone ridges with *Prostanthera striatiflora*, *Eriostemon difformis* and *Eucalyptus morrisii* (at Cobar—Andrews s.n., -xi.1910), in rocky crevices in tall shrublands with *Acacia doratoxylon* and *Eucalyptus viridis* (near Cobar—Crisp 4289), on stony hills with upturned shales and slates (Mt Nurri—Burbidge 6610), in red-brown gravelly sand with *Codonocarpus cotinifolius* and *Casuarina cristata* (Yuleba—Johnson 647), in stands of *Eucalyptus viridis* dominated Mallee communities (Goonoo forest—Willis & Althofer s.n.), and in mixed open forests on shallow hard grey soil (Glenmorgan—Blake 21268). Although rare, this species is often locally common. Altitudes 500-c. 600 m.

Notes

The type material of *P. ringens* was collected by Drysdale from near 'Camp 29' (Mitchell 1848, map 4) while Mitchell was exploring north and north-west of this base camp. Whether the collections were made from near the Maranoa river or from the the adjacent ranges is not clear (Mitchell 1848, p. 361). Although it appears that two collections were made on separate days, only one specimen is present on the NSW sheet. According to J. Carrick (*in adnot.*) a part of Mitchell 577 & 570 was sent from K to NSW in April 1915 (presumably NSW 126717). Whether the K or NSW material individually represent Mitchell 570 or 577 is not known. Since I have not examined the K material, lectotypification is delayed.

White (1944) incorrectly included *P. lepidota* in section *Prostanthera* [as 'Euprostanthera'] series *Subconcavae* Benth. and he concluded that its closest *affinities* were probably with *P. lithospermoides* F. v. Muell. Although the affinities of *P. ringens* are not clear, it is possibly distantly related to *P. aspalathoides*.

This species is characterized by the more or less flat leaves, the insertion of the prophylls near the base of the pedicel, and by the usually green to blue-green corolla (which is unusual in the *prostantheras* of Queensland and New South Wales).

There are two more or less distinct forms (*viz.* a broad-leaved group and a narrow-leaved group—Figs 71B & 71A, respectively).

Key to the groups

- 1a. Leaf lamina length to width ratio (1.5-) 3-5 (-7.5); lamina width (1.5-) 3-4 (-6) mm .. Broad-leaved group
- 1b. Leaf lamina to width ratio (7.5-) 8-15; lamina width 0.9-1.5 (-2) mm Narrow-leaved group

The New South Wales populations of the broad-leaved group are mostly confined to the 'semi-arid' (BSfh) region (Köppen 1936) (\approx warm semi-arid [DB'd] region, Thornthwaite, 1933), refer figure 72. The narrow-leaved group is mostly confined to the 'Subhumid' (Cfa) region (Köppen 1936). Using Gentili's *Annual Phytohydroxeric Index* (Gentili 1972) as a measure of the bioclimatic environment, the broad-leaved plants occur in the 'semi-arid' to 'arid' regions, with phytohydroxeric indices between 2 and 5 (refer, Fig. 72). This is equivalent to the Arid Moisture region of Gentili (1972). Narrow-leaved plants occur in the 'subhumid' bioclimatic region, with phytohydroxeric indices equal to 5 and up to 10. This is equivalent to the SemiArid Moisture region (Gentili 1972). These annual phytohydroxeric values appear to reflect climatic zones which largely control the biomass of the vegetation. Gentili regards the threshold value 5 as the average limit between 'subhumid' and 'semi-arid' climates. The former normally supports an open woodland, whereas the latter supports a scrub or grass formation. The threshold value 3 is the average limit between 'semi-arid' and 'arid' climates. In New South Wales, there is a close correspondence between these phytohydroxeric values, moisture regions and the

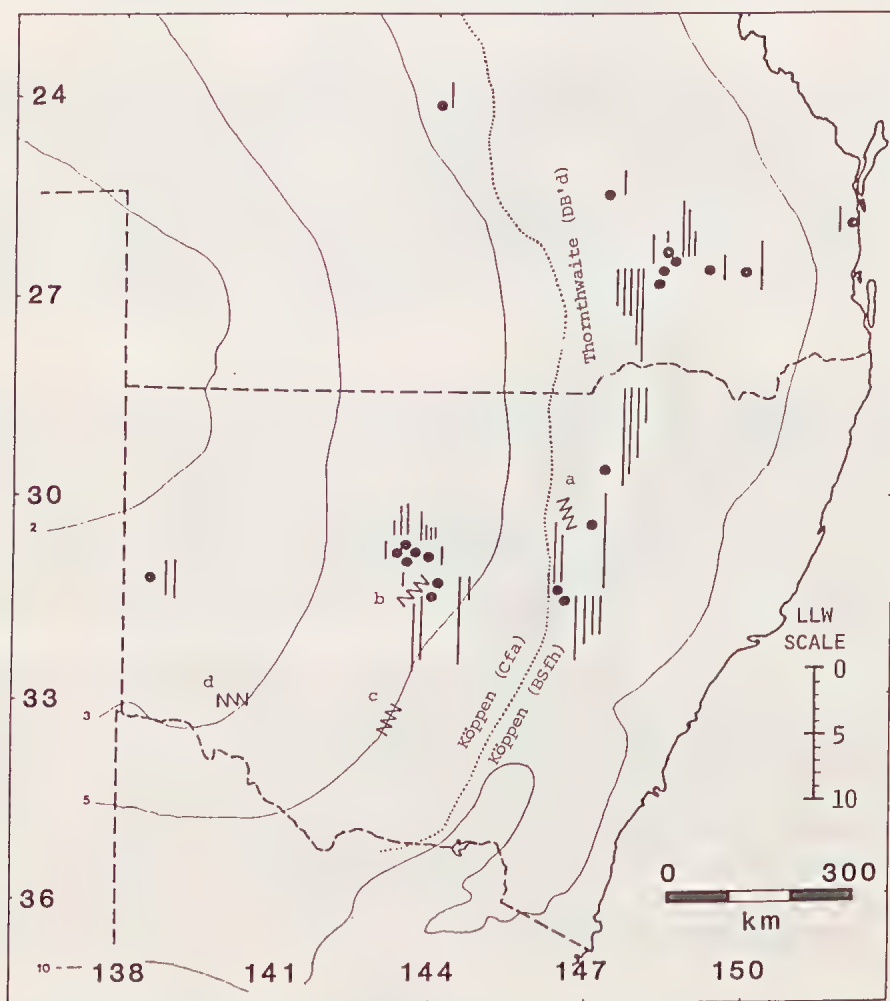


Fig. 72. Distribution map of *Prostanthera ringens*. Histograms are of lamina length to lamina width ratios (LLW). a, b, c, & d = areas of steep climatic gradients in the frequency of arid years. Gentili's phytohydroxeric indices, Köppen's Arid/Semi-arid, and Thornthwaite's Warm semi-arid boundary (dotted line) are superimposed onto map.

type of community in which each group of plants occur. However, in the Darling Downs area of Queensland, there are a number of broad-leaved plants occurring with the narrow-leaved form (Fig. 72). The reasons for the mixture of forms in this region is not immediately obvious. However, the Darling Downs are climatically marginal, such that the transition from 'humid' to 'semi-arid' may be quite sudden and sweeping alternations are possible (Gentilli 1972).

The most consistently semi-arid areas are in the Tambo-Enniskillen (e.g. *White* 12404) and Maranoa-Balonne (e.g. *Mitchell* 577 & 570) areas.

There are a number of areas of New South Wales which have steep climatic gradients in frequency of arid years. Steep climatic gradients occur between Baradine and Coonamble (Fig. 72-a) and between Nymagee and Cobar (Fig. 72-b); other steep climatic gradients are marked on Fig. 72, c-d. In other parts of the State, there is a more gradual increase in aridity to the west and north-west. These steep gradients (particularly, Fig. 72-b) may explain the relatively sharp disjunction between the Cobar and Nymagee populations, and in general, they may act as part of the climatic boundary between these two groups.

A number of plants have been cultivated (e.g. at Burrendong Arboretum, Canberra Botanic Garden and Adelaide Botanic Gardens) and these have retained their phenotypic distinctness. Therefore, it seems likely that the two groups are also genetically distinct. Since most specimens have been cultivated from cuttings taken from the original population (only *Althofer* s.n., 23.i.1944 cultivated from seed), we do not know the extent of the variability within each population. Detailed population studies are necessary to evaluate the ecotypic distinctness of these two groups.

Common names: Gaping mint-bush (Bailey 1883); Green-flowered mintbush (Cunningham *et al.* 1982).

Selected specimens examined (55 collections)

QUEENSLAND.—Darling Downs: *C. White* 13056, 4.x.1946, Kogan (CANB); *Everist* s.n., -x.1969, ENE of Dalby, on road to Kogan (NSW 128469).

NEW SOUTH WALES.—North Western Slopes: *G. Althofer* s.n., -ix.1968, Pilliga Forest, Narrabri (AD).—Central Western Slopes: *Willis & Althofer* s.n., 9.x.1969, Mendooran road, in western portion of Goonoo Forest (AD 97609140, MEL 43326).—North Western Plains: *G. Cunningham* 719, 11.vii.1973, 'The Peak', Cobar (AD).—North Far Western Plains: *Kaspiew* 67, 3.x.-, Broken Hill (S).

12. *Prostanthera grylloana* F. v. Muell., *Fragm.* 10 (1876) 17; Briq., in Engl. & Prantl, *Nat. Pflanzenfam.* 4: 3a (1895) 220; Diels & Pritz, *Bot. Jahrb.* 35 (1904) 526, t. 59; C.A. Gardner, *Enum. pl. austral. occid.* (1931) 114; Blackall & Grieve, *W. Austral. wildfl.* 3 (1965) 594; J.S. Beard, *Descr. cat. W. Austral. pl. (s. dat. [Oct. 1965])* 94; Althofer, *Cradle of Incense* (1978) 78, 80, 82.

Holotype: *Young* s.n., 10-15.x.1875, near Ularing, Western Australia (MEL 41915).

Small erect shrub, 0.3-1.5 m high. *Branches* subterete to quadrangular, densely short-pilose from one leaf axis to next nodal region alternately. *Leaves* both clustered on short branches and arranged along main axis and branches, glabrous, glandular; *petiole* up to c. 1 mm long, often indistinct from lamina, deeply grooved on adaxial surface; *lamina* \pm spatulate 3-5 (-10) \times 2 (-3) mm [length to width ratio 2-3.7 (-6), distance of maximum width from base to total lamina length 0.67-0.9], recurved, coriaceous; adaxial surface deeply grooved such that both sides almost touching each other; base decurrent almost to base of petiole; margin entire, very slightly undulate; apex \pm rounded; venation not visible. *Pedice*l 1-1.5 (-2) mm long, shortly tomentose; *prophylls* inserted 0.5-0.8 mm from distal end of



Fig. 73. *Prostanthera grylloana*.—A. twig and flowers; B. detail of leaf, pedicel, prophylls and calyx; C. flower—abaxial view; D. open corolla; E. stamens—ventral and dorsal views (all *Willis s.n.*, MEL 43160).

pedical, usually just overlapping with basal part of calyx, linear to narrow-oblong, c. 1 x 0.1 mm, soon falling off, the slightly enlarged basal part remaining (which is c. 0.2 mm long and 0.2 mm wide), minutely tomentose basally; apex subacute. *Calyx* 4-6 mm long; outer surface sparsely tomentose throughout; hairs c. 0.1 mm long; *tube* 4-4.5 mm long; inner surface glabrous; *lobes* \pm triangular, c. 2 mm long, 3-4 mm wide at base; inner surface densely, minute-pilose; hairs up to c. 0.1 mm long; margin entire; apex obtuse. *Corolla* (12-) 15-20 mm long, red to dull medium mauve-pink; outer surface distally sparsely tomentose; *tube* 10-14 mm long; inner surface glabrous; *lobes* glabrous basally on inner surface, sparsely tomentose distally especially near apex and margin; *abaxial median lobe* \pm triangular, c. 5 mm long, 2-3 mm wide at base; margin \pm entire to slightly irregular; apex obtuse to subacute; *lateral lobes* \pm triangular, c. 2.5 mm long, c. 2.5 mm wide at base, \pm erect; margin entire, fimbriate; apex obtuse to subacute; *adaxial median lobe-pair* broadly oblong-ovate, 3.5-4 mm long, c. 4 mm wide at base; margin entire; apex rounded, emarginate; sinus up to 1 mm long. *Stamens* inserted c. 13 mm above base of corolla; filaments 4-5 mm long; anthers 1-1.5 mm long; base of lobes with small acumen up to 0.3 mm long; connective extended on one side to form a basal appendage 2-2.5 mm long, with a few \pm triangular trichomes. *Pistil* 20-24 mm long; ovary c. 0.3 mm long; style 19-21 mm long; stigma lobes up to 0.5 mm long. *Mericarps* c. 2 mm long, distally c. 0.5 mm extended beyond base of style; seed unknown. Figs 73 & 74.

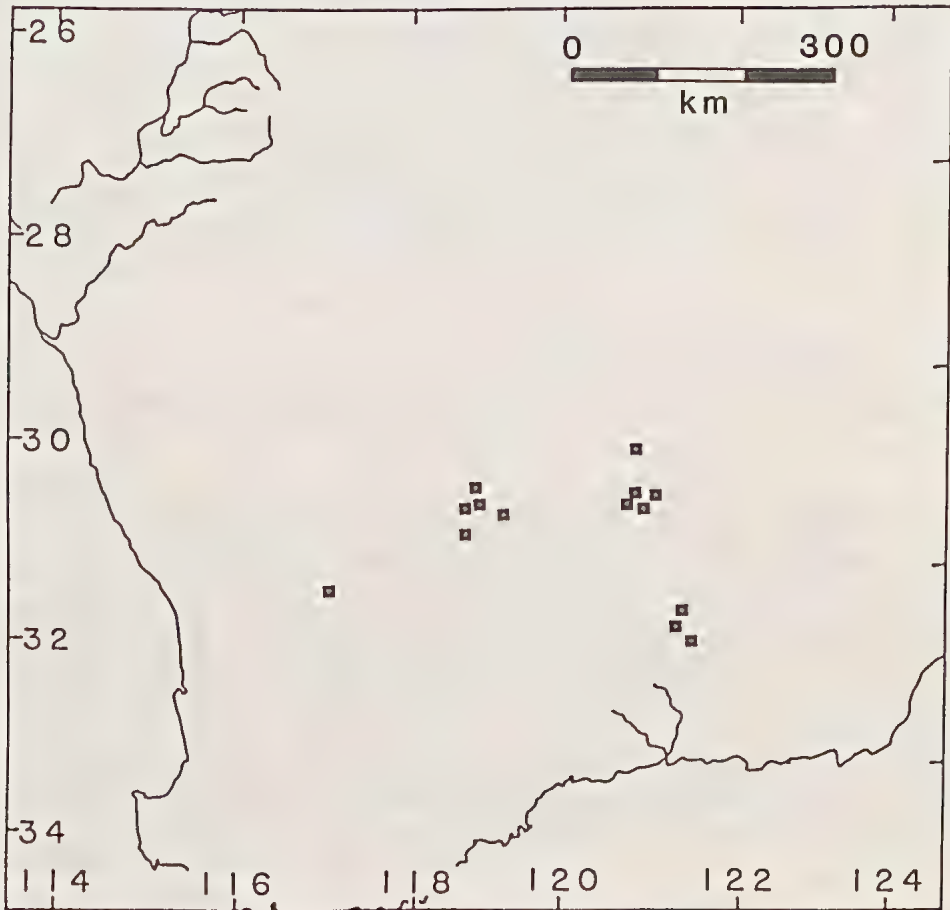


Fig. 74. Distribution map of *Prostanthera grylloana*.

Distribution

Western Australia (Eremaean: Helms, Austin, Coolgardie; South-West: Avon, Roe).

Conservation status: considered not at risk.

Ecology

This species occurs on sandy soils, frequently amongst granite outcrops on granitic loamy sands, or on compacted red clay-loams with laterites. Commonly associated with open dry sclerophyll woodland communities of *Acacia* spp., *Casuarina acutivalvis*, *C. campestris*, and *Eucalyptus* spp.

Note

P. grylloana is readily identified by its more or less conduplicate spatulate leaves. The outer surface of the calyx may appear glabrous because of the sparse indumentum and the very small hairs (cf. *Eaton s.n.*, MEL 1512004). The affinities of this species are not clear.

Selected specimens examined (60 collections)

WESTERN AUSTRALIA.—Eremaean: Helms: *Helms s.n.*, 16.ix.1891, Victoria Desert camp 54 (AD 96911024)—Austin: *Fitzgerald s.n.*, -x.1898, Bardoc (NSW 126688, 126690, 126691); *Fraser 434/22*, -viii.1919, between Mt Marshall and Lake Barlee (NSW); *Gardner & Blackall s.n.*, -ix.1927, Comet Vale (PERTH); *Jutson 277*, -viii.1917, Comet Vale (NSW).—Coolgardie: *Alpin 1886*, 9.ix.1962, 23 miles S of Coolgardie (PERTH); *Blackall 950*, 11.x.1931, near Bullabulling (PERTH); *Chinnock 3114*, 19.ix.1976, 40.2 km NNW of Bullfinch (AD); *Davies 211*, 2.v.1963, Spargoville (PERTH); *George 4245*, 22.ix.1962, 20 miles SW of Coolgardie (PERTH); *Helms s.n.*, 12.xi.1891, Gnarlbin (AD 96911025, MEL 41914, NSW 126692); *Phillips s.n. (CBG 26145)*, 6.ix.1968, 22 miles from Coolgardie towards Norseman (AD 96920341); *Short 923*, 12.xi.1979, Wargangering Rock (AD); *Wilson 3461*, 22.ix.1964, c. 1 km E of Wargoolan (AD). South-West: Avon: *Blackall 862*, 3.x.1931, near Campion (PERTH); *Chinnock 3127*, 20.ix.1976, 9.8 km S of Warralakin (AD); *Chinnock 5058*, 6.xii.1980, 3 km NNE of Westonia (AD); *Wilcox s.n.*, -iv.1954, Warralakin Rock (PERTH); *Merrall s.n.*, anno 1888, E sources of Swan River (MEL 43877).—Roe: *Brockway 8*, -x.1944, Grasspatch (PERTH); *Phillips s.n. (CBG 19296)*, 6.xi.1962, 1 miles N of Salmon Gums (NSW); *Wrigley s.n. (CBG 33671)*, 12.xi.1968, 99 miles N of Esperance (AD, CBG).

13. *Prostanthera monticola* Conn, *sp. nov.*

P. walteri auct. non F. v. Muell. (1870): C. Moore, Handb. fl. New S. Wales (1893) 352; Dixon, Pl. New S. Wales (1906) 232; Harris, Alpine pl. Austral. (1970) 142, *p.p.*; Galbraith, Wildfl. SE Austral. (1977) 326, *p.p.*

**Prostanthera* *sp. aff. P. walteri*: Althofer, Cradle of Incense (1978) 116.

Species nova Sectionis Klanderiae. *Frutices* 0.3-2 m. alti. *Rami* et *ramuli* subteretes usque subquadrangulares, tomentosi, pilis appressis, 0.3-0.4 mm. longis, internodiis iuvenibus saepe octo-porcatis. *Petiolus foliorum* (1.5-) 2-5 mm. longus, tomentosus usque glabrescens; *lamina* angusta, ovata usque elliptica, 15-50 mm. longa, 5-13 mm. lata, pagina abaxiali glabra, pagina adaxiali sparsim tomentosa vel glabra, basi cuneata usque subacuta, margine integro, recurvo, apice obtuso. *Pedicellus florum* 2-3 mm. longus, dense tomentosus, pilis circa 0.1 mm. longis, *prophyllis* ad basim calycis affixis, 10-18 mm. longis. *Calyx* 10-15 mm. longus, extra ad basim sparsim tomentosus usque glabrescens, alibi glaber; *tubus* 5-6 mm. longus; *lobi* ovati usque deltoidei, 6-9 mm. longi, 4-5 mm. lati, intra tomentosi, pilis circa 0.1 mm. longis, margine integro, apice obtuso usque angusto-acuto. *Corolla* 30-35 mm. longa, veneta; *tubus* 18-20 mm. longus, extra in partibus distalibus sparsim tomentosus; *lobi* intra sparsim tomentosi vel glabri, *abaxiali-mediano* plus minusve suborbiculari, 8-10 mm. longo, circa 10 mm. lato, margine irregulari, apice plus minusve rotundato, emarginato, sinu circa 1 mm. longo, *lateralibus* deltoideis, 7-8 mm. longis, circa 5 mm. latis, margine integro, apice subacuto usque acuto, *adaxiali-mediano* plus minusve ovato, leviter trilobio, circa 10 mm. longo, circa 12 mm. lato, margine integro, apice plus minusve obtuso, emarginato, sinu circa 1 mm. longo. *Stamina* circa 11 mm. e basi corollae affixa; filamenta 10-13 mm. longa; antherae 1.5-2 mm. longae, connectivo per trichomata deltoidea ultra loculis producto. *Pistillum* circa 25 mm. longum; ovarium circa 0.5 mm. longum; stylus 18-22 mm. longus; lobis stigmatibus circa 1 mm. longis. *Fructus* coccis 1.5-2 mm. longis.

Holotypus: Conn (& Campbell) 731, 4.ii.1980, Crystal Brook Falls, Mt Buffalo, Eastern Highlands, Victoria (MEL; iso in AD, CANB).

Sprawling, open shrub, 0.3-2 m high. *Branches* subterete to subquadrangular, often with approximately 8 ridges distally, red, hairy, densely so on upper internodes and nodes; hairs appressed, 0.3-0.4 mm long, white. *Leaves* arranged along main axis and branches, not clustered; *petiole* (1.5-) 2-5 mm long; upper surface grooved, reddish when young, tomentose basally, sparsely tomentose to glabrescent distally; hairs c. 0.1 mm long, white; *lamina* narrow, ovate to elliptic, 15-50 x 5-13 mm [lamina length to width ratio 3-6.7; ratio of distance maximum width from lamina base to total lamina length 0.3-0.5], coriaceous; abaxial surface glabrous; adaxial surface sparsely tomentose (hairs c. 0.2 mm long, white) or glabrous; base cuneate to subacute; margin entire, recurved; apex obtuse; venation faint to indistinct; midrib raised on abaxial surface (usually with a few scattered hairs), sunken on adaxial surface (usually with red wart-like glands). *Pedicel* 2-3 mm long, flattened, densely tomentose; hairs c. 0.1 mm long, white; *prophylls* inserted at distal end of pedicel and so overlapping calyx, \pm linear, 10-18 mm long, equal to length of calyx or often extended beyond calyx, usually recurved, concave; abaxial surface sparsely minute-tomentose basally, glabrous distally; adaxial surface glabrous; apex \pm obtuse. *Calyx* 10-15 mm long, green; outer surface sparsely tomentose to glabrescent basally, glabrous distally; *tube* 5-6 mm long; inner surface with scattered pedicellate glandular trichomes; *lobes* ovate to triangular, 6-9 mm long, 4-5 mm wide at base; inner surface minutely hairy; hairs c. 0.1 mm long; glabrous at apex; margin entire (not ciliate); apex obtuse to tapering-acute; apex of abaxial lobe often more obtuse than adaxial lobe. *Corolla* 30-35 mm long, pale blue-green to grey-green, with dark purple-blue veins; *tube* 18-20 mm long, sparsely tomentose distally, especially medially and towards margin; *lobes* sparsely tomentose on outer surface; hairs c. 0.2 mm long; *abaxial median lobe* \pm semi-orbicular, 8-10 mm long, c. 10 mm wide, sparsely pilose-tomentose medially; margin irregular; apex \pm rounded, emarginate; sinus c. 1 mm long; *lateral lobes* triangular, 7-8 mm long, c. 5 mm wide at base; inner surface sparsely pilose-tomentose; margin entire; apex subacute to acute; *adaxial median lobe-pair* \pm ovate, faintly 3-lobed, c. 10 mm long, c. 12 mm wide at base; inner surface glabrous, except often sparsely pilose-tomentose near margin between faint lobes; margin entire; apex \pm obtuse, emarginate; sinus c. 1 mm long. *Stamens* inserted c. 11 mm above base of corolla; filaments 10-13 mm long; anthers 1.5-2 mm long; base of lobes with small acumen; connective slightly extended basally, with deltoid trichomes present, trichomes c. 0.2 mm long. *Pistil* c. 25 mm long; ovary up to c. 3 mm long, diameter at base c. 1 mm, lobes small; style 18-22 mm long; stigma lobes c. 1 mm long. *Mericarps* 1.5-2 mm long, distally extended c. 1 mm beyond base of style. Figs 75 & 76.

Distribution

New South Wales (Southern Tablelands) and Victoria (Eastern Highlands).

Conservation status

Although the distribution of this species is restricted, it is not considered to be endangered or vulnerable—Risk code = 3R,C ([Conn, in] Leigh *et. al*, 1981, pp. 49 & 104 [as *P. walteri*] assigns a risk code value of 2R to this species).

Ecology

Commonly associated with *Eucalyptus delegatensis*, *E. pauciflora* (*E. niphophila*), *E. perriniana*, *E. stellulata* or *E. viminalis* woodlands, commonly growing with *Boronia alga*, *Bossiaea foliosa* and/or *Oxylobium alpestre*, on deeply weathered granitic soils amongst granitic rocks. Altitude 530-1833 m.

Note

This species is very closely related to *P. walteri*. *P. monticola* has longer prophylls



Fig. 75. *Prostanthera monticola*.—A. twig and flowers; B. detail of leaves, pedicel, prophylls, calyx and style; C. open corolla; D. stamens—ventral and dorsal views; E. part of calyx removed to reveal mericarps and style (all Carrick 3125).

(10-18 mm long *cf.* 4-6.5 mm long in *P. walteri*) and the inner surface of the calyx-lobes are hairy (glabrous in *P. walteri*). Frequently, *P. walteri* has longer hairs on the vegetative parts than does *P. monticola* and the density of hairs is usually greater in the former species.

Both species appear to occupy a unique 'position' within sect. *Klanderia*. Both have large petiolate leaves (petiole 1.5-8 mm long; lamina 10-50 x 5-17 mm) which are more typical of sect. *Prostanthera*. The preliminary results from the volatile leaf oil analysis (p. 284) suggest that both species have very low amounts of terpenoids, whereas all other species of this section (which have been sampled) are relatively rich in terpenoids. Furthermore, *P. monticola* and *P. walteri* are the only species of sect. *Klanderia* which occur above the snow-line.

Selected specimens examined (49 collections)

NEW SOUTH WALES.—Southern Tablelands: *Ashby 2086* (collected by Stead), 16.i.1967, Schlink Pass road, near Geehi River crossing, Mt Kosciusko National Park (AD); *Briggs 2542*, 10.ii.1969, ½ mile NW of Round Mt (AD); *Costin s.n.*, 15.ix.1948, Big Badja Mountain (NSW 126710); *Gittins 415*, -i.1962, Dickie Cooper Creek (NSW).

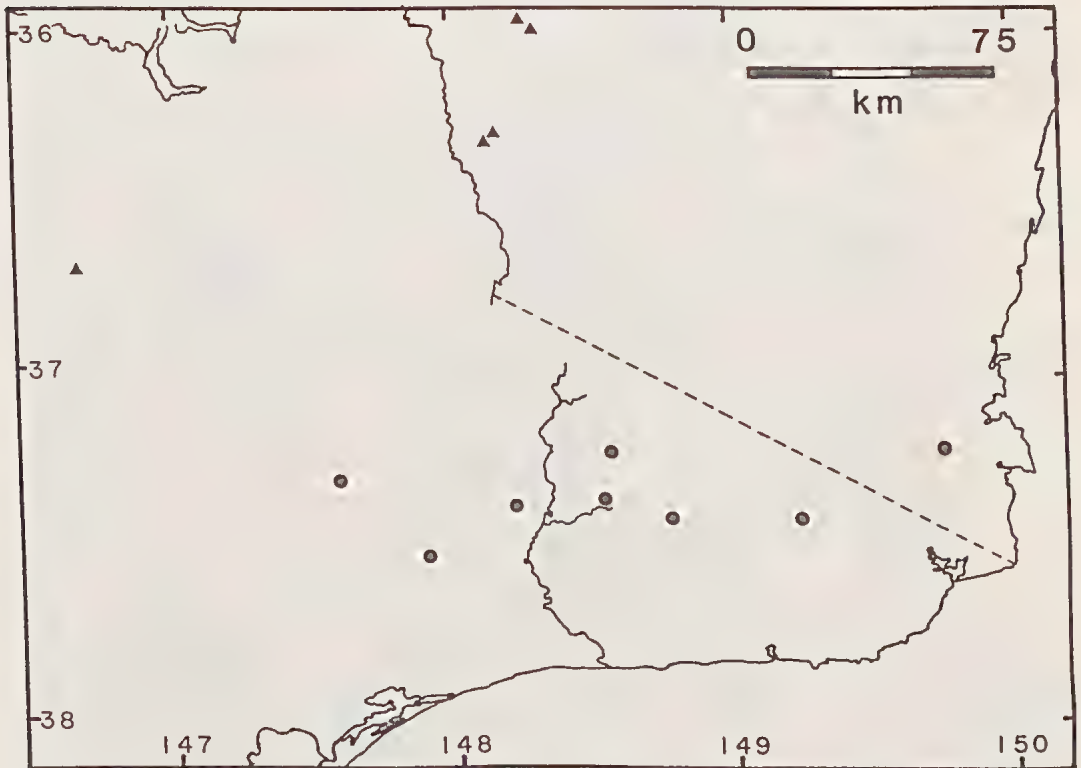


Fig. 76. Distribution map of *Prostanthera monticola* (▲) and *Prostanthera walteri* (●).

VICTORIA.—*Beaglehole* 17096, -i.1950, lookout above where Crystal Brook drops down, Mt Buffalo (AD); *Beaglehole* 41681, 28.iii.1973, Mt Buffalo National Park, below Chalet (AD); *Briggs s.n.*, 23.xii.1952, near Chalet, Mt Buffalo National Park (NE); *Cabbage* 3686, 19.i.1913, Mt Buffalo (NSW, SYD); *Carlisle s.n.*, -iii.1893, Buffalo ranges (MEL 41923); *Carrick* 3011, 6.xii.1971, Mt Buffalo (AD); *Conn & Campbell* 731-735, 4.ii.1980, Crystal Brook Falls, Mt Buffalo (AD); *Dunlop s.n.*, 14.i.1969, Creek below dam wall of Lake Catani, Mt Buffalo (CBG); *French s.n.*, -xii.1904, Buffalo ranges (MEL 41920, MEL 91921); *Gauba* 3305, 10.ii.1955, Mt Buffalo (AD); *Gray & Totterdell* 5826, 17.xii.1965, Mt Buffalo (CANB, NSW); *Hill* 1263, 31.xii.1963, Mt Buffalo plateau (AD); *Kinnear s.n.*, -i.1953, Mt Buffalo (AD); *Muir* 653, 2.i.1959, near Lake Catani, Mt Buffalo (AD, MEL, NSW); *Nettie s.n.*, -i.1923, Buffalo Mts (NSW 126711); *Short* 1383, 27.i.1982, c. 200 m down from summit of Mt McLeod (MEL); *Walter s.n.*, -xi.1903, Buffalo Mts (MEL 41922); *Weindorfer s.n.*, 28.xii.1902, Buffalo Mts (NSW); *Weindorfer s.n.*, -xii.1903, Buffalo Mts (NSW 126714); *Williamson s.n.*, 30.xii.1918, Buffalo Mts (NSW 126712); *Willis s.n.*, 18.ii.1963, Mt Buffalo National Park (MEL 43787).

14. *Prostanthera walteri* F. v. Muell., *Fragm.* 7 (1870) 108; *Key Vict. pl.* 2 (1885) 42; *op. cit.* 1 (1887) 386; Guilfoyle, *Austral. pl.* (1911) 306; Pescott, *Nat. fl. Victoria (s. dat.* [1914]) 99; Ewart, *Fl. Victoria* (1930) 982; Harris, *Alpine pl. Austral.* (1970) 142, p.p.; Galbraith, *Wildfl. SE. Austral.* (1977) 326, p.p.; Althofer, *Cradle of Incense* (1978) 116, 119, 121, 122.

Holotype: *C. Walter s.n.*, anno 1870, 'Mt Ellery, Gippsland', Victoria (MEL 41927).

Sprawling shrub, 1-2 m high. *Branches* forming a tough wiry entanglement, \pm terete, densely \pm patent-pilose to appressed-tomentose; hairs (0.5-) 0.8-1 (-1.5) mm long and 0.1-0.3 mm long, respectively, strongly curved when indumentum tomentose, glandular. *Leaves* arranged along main axis and branches, not clustered; *petiole* 2-5 (-8) mm long; adaxial surface grooved, hairy, as for branches; *lamina* ovate to slightly rhombic, (10-) 18-26 (-38) x 5-15 (-17) mm [lamina length to width ratio 1.4-2.5; ratio of distance maximum width from lamina base to total lamina length 0.2-0.45]; abaxial surface pilose to tomentose, with hairs 0.5-0.8 mm long and 0.3-0.4 mm long respectively, strongly curved when indumentum tomentose; adaxial surface appearing glabrous, however sparsely minute-tomentose, especially on midrib, with hairs up to c. 0.1 mm long; base obtuse, subacute to cuneate; margin entire, recurved; apex obtuse; venation faint; midrib raised on abaxial surface, slightly sunken on adaxial surface; veins mostly indistinct, slightly raised on abaxial surface, very slightly sunken adaxially. *Pedice* 3-6 mm long, hairy, as for branches; *prophylls* inserted near distal end of pedice (within 1 mm of calyx) and so overlapping calyx, linear-obovate, 4-6.5 mm long, usually recurved, concave; abaxial surface sparsely hairy to glabrescent; adaxial surface glabrous; margin recurved; apex obtuse. *Calyx* 10-12 mm long, striate; outer surface pilose throughout or \pm pilose at base, becoming glabrous or sparsely tomentose distally, or glabrous throughout; inner surface glabrous; *tube* 4-5 mm long; *lobes* broadly ovate, 3-6 (-7) mm long, 5-7 mm wide at base; margin entire; apex obtuse to rounded. *Corolla* (15-) 18-26 mm long, blue-green, rarely green-yellow, prominently purple-veined; *tube* 12-16 mm long, diameter at mouth 4-7 mm; outer surface sparsely tomentose distally; hairs up to 0.2 mm long; inner surface glabrous; *lobes* sparsely short-tomentose on outer surface, becoming denser near margin; inner surface glabrous; *abaxial median lobes* \pm spatulate, 5-10 x 3-9.5 mm, c. 1.5 mm wide at base; apex rounded, irregular, slightly lobed; *lateral lobes* narrow oblong-ovate, (4-) 5-7 (-10) mm long, 1-1.5 mm wide at base; apex obtuse; *adaxial median lobe-pair* broadly ovate, 5-10 mm long, 6-10 mm wide at base; apex obtuse, slightly emarginate; sinus c. 0.5 mm long. *Stamens* inserted c. 10 mm above base of corolla; filaments c. 6 mm long, often with broad-deltoid glandular trichomes; anthers 1.5-2 mm long; base of lobes with small acumen; connective often extended on one side to form a basal appendage c. 0.4 mm long, with narrow-deltoid trichomes usually present, or appendage absent. *Pistil* 20-27 mm long; ovary 1-1.5 mm long, diameter at base c. 1 mm, lobes small; style 18-23 mm long; stigma lobes 0.5-1 mm long. *Mericarps* c. 2 mm long, distally extended c. 0.6 mm beyond base of style. Figs 76 & 77.

Distribution

New South Wales (South Coast) and Victoria (Eastern Highlands—East Gippsland).

Conservation status

Although the distribution of this species is restricted, it is not considered to be endangered or vulnerable—Risk code = 3R ([Conn, in] Leigh *et al.*, 1981, pp. 49 & 110 assigns a risk code value of 2R to this species).

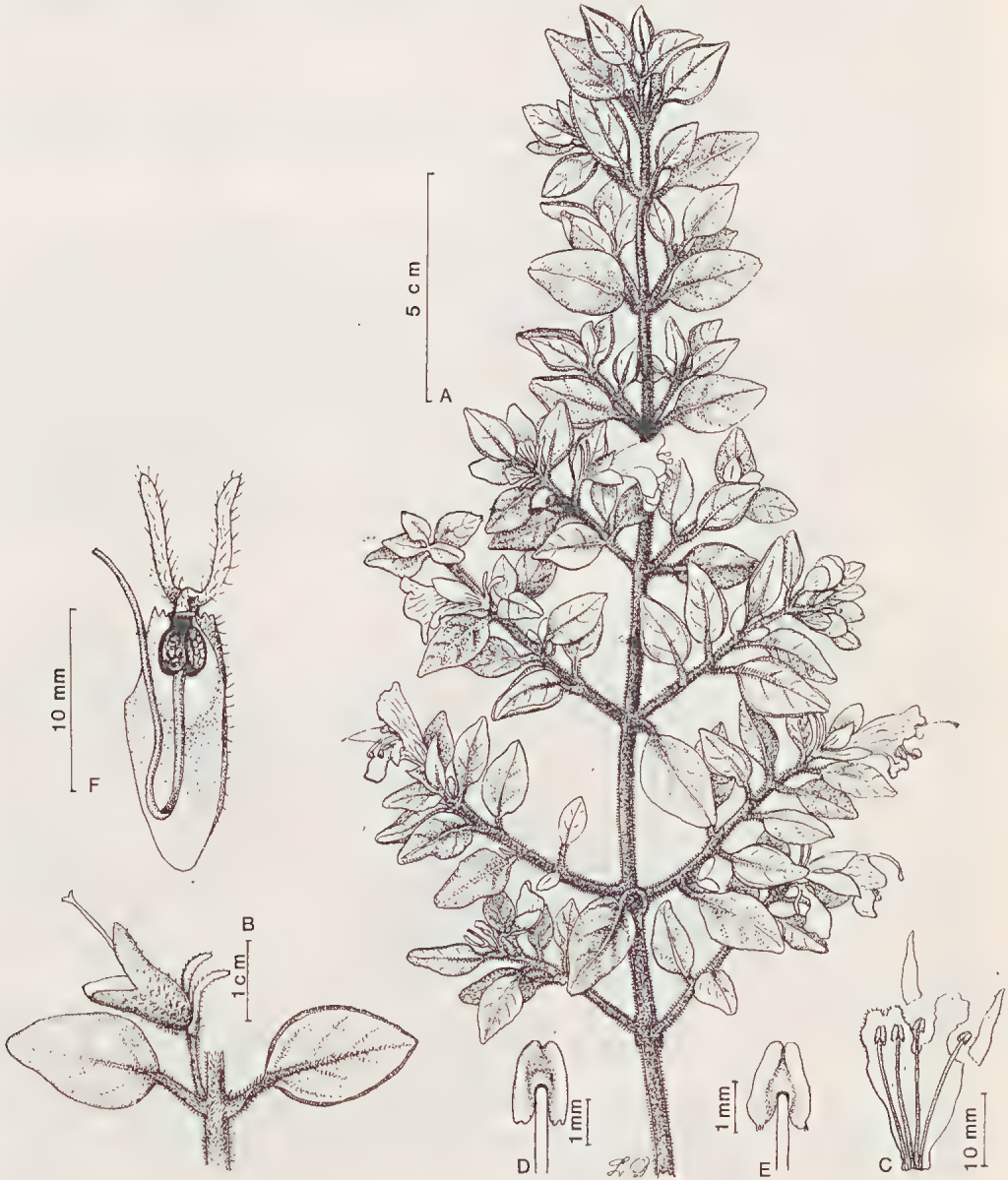


Fig. 77. *Prostanthera walteri*.—A. twig and flowers; B. detail of leaves, pedicel, prophylls, calyx and style; C. open corolla; D. stamens—dorsal view; E. stamens—ventral view; F. part of calyx removed to reveal mericarps and style (all Carrick 3033).

Ecology

Commonly occurring in granitic soils, associated with *Eucalyptus imlayensis*, *E. obliqua*, *E. regnans*, *E. sieberi*, *E. viminalis*, *Blechnum wattsii*, *Dicksonia antarctica*, *Eriostemon virgatus*, *Oxylobium ellipticum* and *Pultenaea juniperina*. Altitude (850-) 1030-1400 m.

Notes

This species is very closely related to *P. monticola*. *P. walteri* is readily distinguishable from *P. monticola* by its glabrous inner surface of the calyx (hairy lobes in *P. monticola*) and by its shorter prophylls. For further details refer 'Notes' for *P. monticola*.

Common names

Blotchy mint-bush (Ewart 1930, Willis 1973): Monkey mint-bush (Willis 1973).

Selected specimens examined (40 collections)

NEW SOUTH WALES.—South Coast: Telford 7256, 5.xii.1978, Mt Imlay (CBG).

VICTORIA.—Eastern Highlands (East Gippsland): Beaglehole 34062, 20.ix.1970, Mt Kaye (AD); Beaglehole 35729, 3.i.1971, Monkey Top Track, S of Bowen Range (AD); Beaglehole 37084, 27.ii.1971, W of Mt Baldhead, Bruthen road (AD); Beaglehole 37111, 28.ii.1971, Mt Elizabeth II, north side (AD); Beaglehole 37726, 2.iv.1971, Yalmy road, Yalmy river area (AD); Carrick 3033, 3036, 8.xii.1971, Summit of Mt Ellery (AD); Conn 709-714, 1.xii.1979, Mt Ellery (AD); Conn 724-726, 2.xii.1979, Mt Elizabeth No. 2 (AD); Czornij 441, 8.xii.1971, Summit of Mt Ellery (AD); French s.n., -i.1889, Summit of Mt Ellery (MEL 41918); French s.n., s. dat. E. Gippsland (P); Hodge s.n., 13.ii.1948, main top E of "W-Tree" (MEL 41929); Hodge s.n., 23.iv.1957, cultivated at W-Tree (MEL 41925); Howitt 15, anno 1884, Gippsland (MEL 41926); Purdie 289, anno 1894, Mt Ellery (MEL 41919); Wakefield s.n., 20.xi.1947, Summit of Mt Kaye, upper Cann River valley (MEL 43784); Walter s.n., anno 1870, Mt Ellery (MEL 41927) (TYPE); Walter s.n., anno 1871, Gippsland (MEL 41917); Willis s.n., 17.xi.1968, Yalmy river track between Buchan & Goongerah (AD 97609146, MEL 43786); Willis & Wakefield s.n., 16.x.1948, Mt Kaye (MEL 43785); Willis & Wakefield s.n., 29.xii.1951, Mt Ellery (AD 97609145, MEL 43782, MEL 43783).

15. *Prostanthera porcata* Conn, sp. nov.

Species nova Sectionis Klanderiae. *Fruites* 1.5-2 m. alti. *Rami* et *ramuli* glabri, dense glandiferi, plus minusve quadrangulares, quadriporcati; *cristae* persistentes et *petiolis* adnatis. *Petiolus foliorum* (2-) 4-8 mm. longus, parum canaliculatus, canali piloso; *lamina* complanata, parum canaliculata basaliter, plus minusve elliptica usque anguste elliptica, (18-) 24-36 mm. longa, (7-) 9-14 mm. lata, basi attenuata, margine integro vel plus minusve minute lobato. *Pedicellus florum* 4-5 mm. longus, glaber, glandifer, *prophyllis* ad basim calycis affixis, plus minusve linearibus, 2.8-5.6 mm. longis, 0.3-0.4 (-0.7) mm. latis. *Calyx* 12-15.5 mm. longus, glaber, glandifer; *tubus* 8-9 mm. longus; *lobi* latissime deltoidei, (4-) 5-7 mm. longi, circa 4-5 mm. lati, margine integro, apice obtuso. *Corolla* (21-) 23-27 (-31) mm. longa, rosea vel crenea basaliter et subrosea distaliter; *tubus* 15-22 mm. longus; *margines loborum* parum fimbriati, *abaxiali-mediano* oblongo usque subspathulato, 3-4.5 mm. longo, circa 3-3.5 mm. latis, margine integro, apice plus minusve truncato et plus minusve irregulari, *lateralibus* ovato-deltoideis, 2-3.5 mm. longis, 2-3 mm. latis, margine integro, apice obtuso, *adaxiali-mediano* plus minusve depresso ovato, 5-6 mm. longo, 9-10.5 mm. lato, margine integro vel saepe parum irregulari, retuso, sinu usque ad 0.5 mm. longo. *Stamina* circa 14-15 mm. e basi corollae affixa; filamenta circa 8-9 mm. longa; antherae 1.3-2 mm. longae, appendice 2-3 mm. longa. *Pistillum* 26-32 mm. longum; ovarium 0.5-1.3 mm. longum; stylus circa 29-32 mm. longus; lobis stigmatibus circa 0.2 mm. longis. *Fructus* immaturi.

Holotypus: Gilmour s.n., 22.vi.1982, 4 km SE. of Mt Budawang, Budawang National Park, New South Wales (MEL 644089; *iso* in AD, CANB 8203466, CBG, K, NSW).

Erect shrub, 1.5-2 m high. *Branches* glabrous, densely glandular [200-350 glands/mm²]; glands hemispherical, branches \pm quadrangular with 4 ridges; ridges persistent (at least distally), adnate to petiole, extending from base of petiole to the next more basal internode, c. 0.3 mm high, crest rounded. *Leaves* arranged along the branches; *petiole* (2-) 4-8 mm long, slightly channelled with abaxial surface glabrous; adaxial surface hairy along midrib with hairs 0.1-0.3 mm long, glandular; *lamina* flattened, slightly channelled basally \pm elliptic to narrowly elliptic, (18-) 24-36 x (7-) 9-14 mm [lamina length to width ratio

(2-) 2.2-3.7; ratio of distance of maximum width from lamina base to total lamina length 0.5-0.7]; base attenuate; margin entire or minutely notched to minutely lobed (sinus less than 1 mm long); apex obtuse to slightly rounded; venation indistinct; midrib raised on abaxial surface and slightly sunken on basal portion of adaxial surface. *Pedicel* 4-5 mm long, glabrous, glandular; *prophylls* inserted up to c. 1 mm from base of calyx, hence overlapping basal part of calyx, \pm linear, 2.8-5.6 x 0.3-0.4 (-0.7) mm [length to width ratio 9.3-14.4], \pm flattened, glabrous, glandular; margin entire; apex subacute to obtuse. *Calyx* 12-15.5 mm long, glabrous, glandular (density c. 225 glands/mm²); *tube* 8-9 mm long, 4-5 mm wide at mouth; *lobes* very broadly triangular, (4-) 5-7 mm long, c. 4-5 mm wide at base; margin entire; apex obtuse. *Corolla* (21-) 23-27 (-31) mm long; cream basally, shading to pink on lobes, or deep pink throughout; *tube* 15-22 mm long; *lobes* with margin sparsely fimbriate; hairs c. 0.1 mm long; *abaxial median lobe* oblong to subspathulate, 3-4.5 mm long, c. 3-3.5 mm wide at base; margin entire; apex \pm truncate, \pm irregular; *lateral lobes* ovate-triangular, 2-3.5 mm long, 2-3 mm wide at base; margin entire;

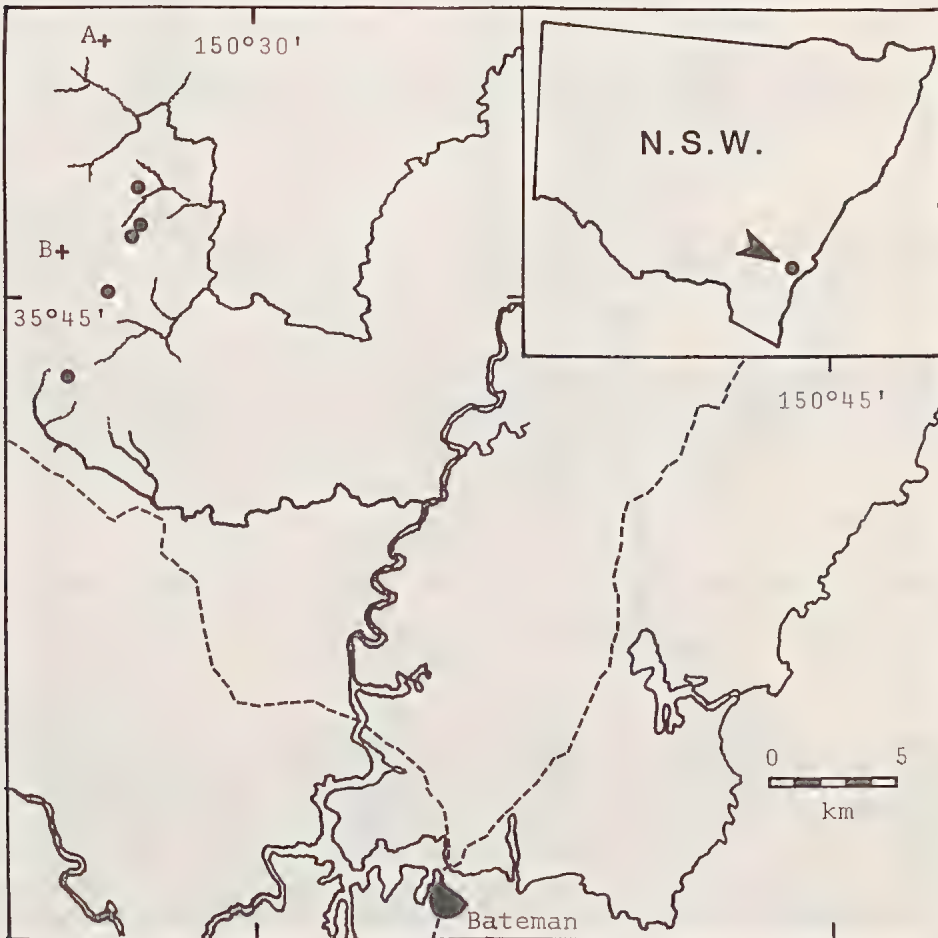


Fig. 78. Distribution map of *Prostanthera porcata*. A = Mt Currockbilly; B = Mt Budawang; major roads in discontinuous lines. Locality of Budawang Range given in insert map.

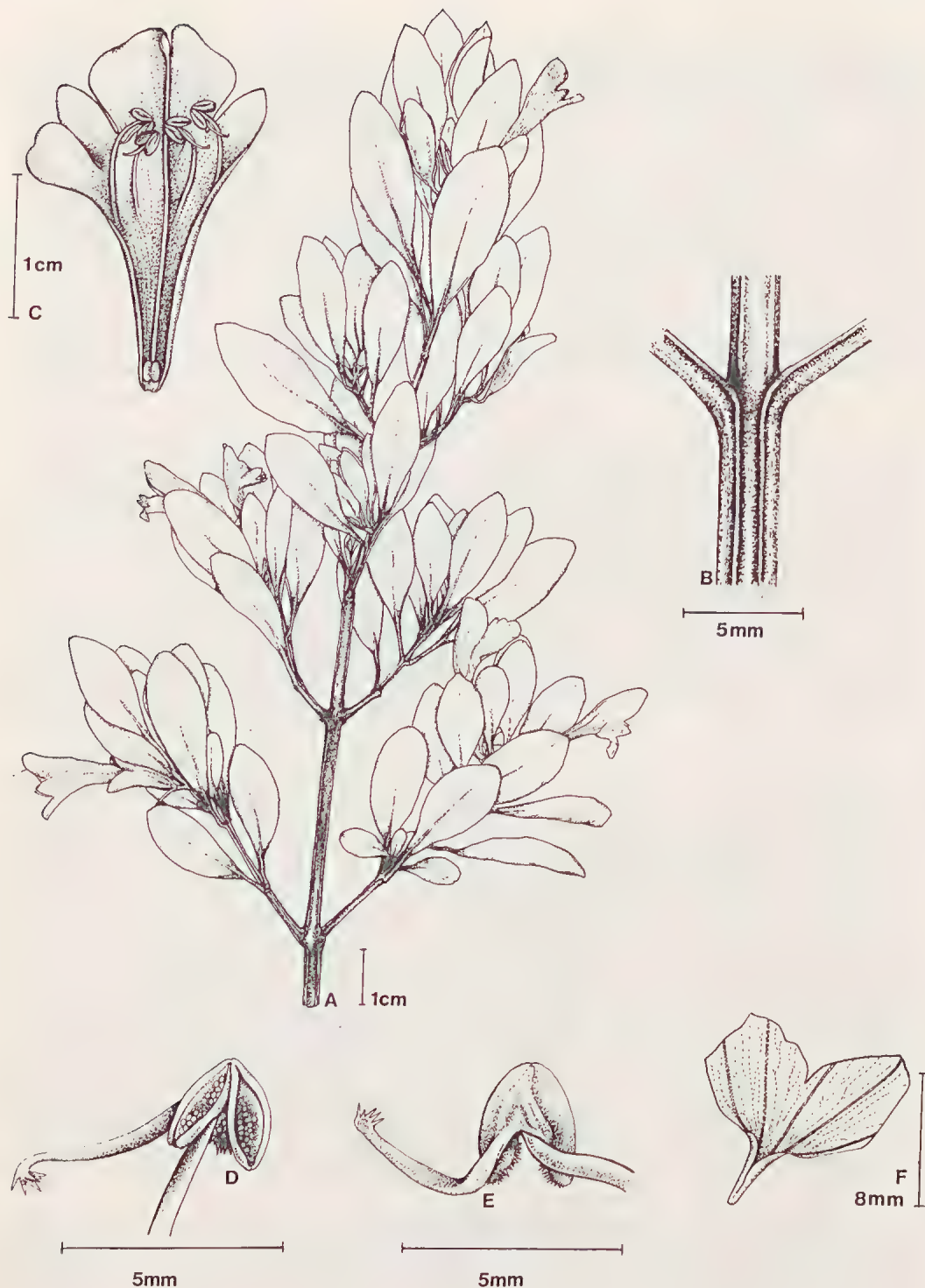


Fig. 79. *Prostanthera porcata*.—A. twig and flowers; B. detail of branch and leaf bases; C. open flowers; D. ventral view of stamens; E. dorsal view of stamen with filament displaced sideways (all *Gilmour CBG 8203466*); F. open calyx showing principal veins (*Telford 8826*).

apex obtuse; adaxial median lobe-pair \pm depressed ovate, 5-6 mm long, 9-10.5 mm wide; margin entire often slightly irregular; apex rounded, retuse with sinus up to 0.5 mm long. *Stamens* inserted c. 14-15 mm above base of corolla; filaments c. 8-9 mm long; anthers 1.3-2 mm long; lobes with a minute acumen up to 0.1 mm long; one side of connective basally extended to form an appendage 2-3 mm long; appendage with linear-triangular trichomes distally (trichomes 0.1-0.2 mm long). *Pistil* 26-32 mm long; ovary 0.5-1.3 mm long, diameter less than 1 mm at base, lobes small, c. 0.2-0.5 mm long; style c. 29-32 mm long; stigma lobes c. 0.2 mm long. *Mericarps* immature. Figs 78 & 79.

Distribution

New South Wales (South Coast).

Conservation status

The conservation status of this species is not known. However it may be endangered or vulnerable since its distribution is very localized—Risk code = 2K,C.

Ecology

Occurs in open *Eucalyptus agglomerata*-*E. sieberi* forest, with *Casuarina littoralis* and *Eriostemon myoporoides*, on steep rocky slopes with skeletal sandy loam soils on metamorphosed sandstone and conglomerates. Altitudes 450-500 m.

Notes

This species is characterized by the 4-ridged quadrangular branches. The relatively large leaves and glabrous inner surface of the calyx suggest affinities with *P. walteri*.

Specimens examined

NEW SOUTH WALES.—South Coast (Budawang National Park): *Gilmour s.n.*, 30.v.1982, Dingo Road, 4 km SSE. of Mt Budawang (CBG 8213090); *Gilmour s.n.*, 13.vi.1982, South Boundary Road, 4 km SE. of Mt Budawang (CBG 8213089); *Gilmour s.n.*, 22.vi.1982, l.c. (AD, CANB, CBG 8203466, K, MEL 644089, NSW); *Telford (& Lockwood) 8825, 8826*, 19.viii.1982, 4 km SE. of Mt Budawang (CBG); (Deva National Park): *Gilmour 4318*, 15.ii.1984, c. 2 km N. of Coondella trig. (CBG).

Nomen sedis incertae

Prostanthera caleyi Benth., Labiat. gen. spec. (1834) 454; in DC., Prodr. 12 (1848) 562.

Type: Caley s.n. in herb. Lambert, s. dat., 'Hab. in Nova Hollandia' (?BM, n.v.).

Notes

The status of this species is unknown and I have not located collections which are referable to the protologue (Bentham 1834). Bentham (1870) also regarded the status of this species as uncertain. He was unable to re-examine the material 'owing to the dispersion of the Lambertian herbarium' (Bentham 1870; also refer Stafleu & Cowan 1979). Since most of Caley's collections are held at the British Museum (BM) (Stafleu & Cowan 1976), it seems likely that the type of this taxon, may be held there. Unfortunately, collections on loan from the British Museum were returned before this taxon was considered.

Bentham (1834) regarded *P. caleyi* as closely related to *P. aspalathoides*. However, the long anther appendage ('*antherarum calcare longiore loculum subaequante*') and the ovate-elliptic leaves makes it less likely to be closely related to this species. Bentham (1870) tentatively suggested that the relationship was possibly more likely to be with *P. chlorantha*.

However, Caley did not visit South Australia (Currey 1966) and so, could not have collected *P. chlorantha* or any species closely related to it. Since he only collected from the eastern States (as far west as Westernport Bay in Victoria, and south to Tasmania), this taxon is probably from section *Prostanthera*.

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References

- Adams, R.P. (1969). "Chemosystematic and numerical studies in natural populations of *Juniperus*". (Unpubl. Ph. D. dissertation. Univ. of Texas, Austin).
Adams, R.P. (1970a). Seasonal variation of terpenoid constituents in natural populations of *Juniperus pinchotii* Sudw. *Phytochemistry* 9: 397-402.
Adams, R.P. (1970b). Chemosystematic and numerical studies of natural populations of *Juniperus ashei* Buch. *Taxon* 19: 728-751.
Adams, R.P. (1970c). Contour mapping and differential systematics of geographic variation. *Syst. Zool.* 19: 385-390.
Adams, R.P. (1972a). Chemosystematic and numerical studies of natural populations of *Juniperus pinchotii* Sudw. *Taxon* 21: 407-427.
Adams, R.P. (1972b). Numerical analysis of some common errors in chemosystematics. *Brittonia* 24: 9-21.
Adams, R.P. (1974). Computer graphic plotting and mapping of data in systematics. *Taxon* 23: 53-70.
Adams, R.P. (1975). Statistical character weighting and similarity stability. *Brittonia* 27: 305-316.

- Adams, R.P. (1979). Diurnal variation in the terpenoids of *Juniperus scopulorum* (Cupressaceae)—summer versus winter. *Amer. J. Bot.* 66: 986-988.
- Adams, R.P. & A. Hagerman (1976). A comparison of the volatile oils of mature versus young leaves of *Juniperus scopulorum*: chemosystematic significance. *Biochem. Syst. Ecol.* 4: 75-79.
- Adams, R.P. & A. Hagerman (1977). Diurnal variation in the volatile terpenoids of *Juniperus scopulorum* (Cupressaceae). *Amer. J. Bot.* 64: 278-285.
- Adams, R.P. & B.L. Turner (1970). Chemosystematic and numerical studies of natural populations of *Juniperus ashei* Buch. *Taxon* 19: 728-751.
- Althofer, G.W. (1978). "Cradle of incense. The story of Australian *Prostanthera*". (Soc. Growing Austral. Plants: Sydney).
- Anderson, R.H. (1961). Introduction. *Contr. New S. Wales Natl. Herb.* New South Wales, Nos 1-18: 1-15.
- Anon. (1971). "Your Australian garden. No. 2. Mintbushes and their relatives". (David G. Stead Mem. Wildlife Res. Foundation Austral.: Sydney).
- Anon. (1977). Canberra botanic gardens—Growing native plants. 7: 157-159.
- Armstrong, J.A. (1979). Biotic pollination mechanisms in the Australian flora—a review. *New Zealand J. Bot.* 17: 467-508.
- Armstrong, J.A. J.M. Powell & A.J. Richards (Eds) (1982). "Pollination and evolution". (Royal Bot. Gardens Trust: Sydney).
- Attaway, J.A., A.P. Pieringer & L.J. Barabas (1967). The origin of *Citrus* flavour components—III. A study of the percentage variations in peel and leaf oil terpenes during one season. *Phytochemistry* 6: 25-32.
- Bailey, F.M. (1883). "A synopsis of the Queensland Flora". (Govt. Printer: Brisbane).
- Bailey, F.M. (1901). Labiatae. In "Queensland flora". Vol. 4, p. 1204. (Govt Printer: Brisbane).
- Bailey, N.T.J. (1959). "Statistical methods in biology". (Hodder & Stoughton: London).
- Ball, H.W. et al. (Eds) (1962). II. Terminology of simple symmetrical plane shapes (chart 1). *Taxon* 11: 145-156, fig. 19.
- Barker, W.R. (1982). Taxonomic studies in *Euphrasia* L. (Scrophulariaceae). A revised infrageneric classification, and a revision of the genus in Australia. *J. Adelaide Bot. Gard.* 5: 1-310.
- Bartling, F.G. (1830). "Ordines naturales plantarum". (Dieterich: Göttingen).
- Beadle, N.C.W., O.D. Evans & R.C. Carolin (1976). "Flora of the Sydney region". (A.H. & A.W. Reed: Sydney).
- Beard, J.S. (1980). A new phytogeographic map of Western Australia. *Western Austral. Herb. Res. Notes* 3: 37-58.
- Bendz, G. & J. Santesson (Eds) (1973). "Chemistry in botanical classification". *Nobel Symposium* 25. (Nobel Foundation: Stockholm & Academic Press: New York).
- Bentham, G. (1834). "Labiatarum genera et species". pp. 448-456. (J. Ridgeway & Sons: London).
- Bentham, G. (1870). Labiatae. In "Flora Australiensis". Vo. 5, pp. 70-137. (Reeve: London).
- Bentham, G. & J.D. Hooker (1876). "Genera plantarum". Vol. 2, pp. 1160-1223. (Reeve & Co.: London).
- Blackall, W.E. & B.J. Grieve (1974). "How to know Western Australian wildflowers. Parts I, II, III". (Univ. Western Australia Press: [Nedlands]).
- Blackburn, D.T. (1980). A generalized distance metric for the analysis of variable taxa. *Bot. Gaz.* 14: 325-335.
- Bonner, J. (1950). "Plant biochemistry". (Academic Press: New York).
- Briggs, B.G. & L.A.S. Johnson (1979). Evolution in the Myrtaceae—evidence from inflorescence structure. *Proc. Linn. Soc. New S. Wales* 102: 157-256.
- Briquet, J. (1895). Labiatae *p.p.* in Engler, A. & K. Prantl (Eds), "Die Natürlichen Pflanzenfamilien". Teil IV, Abteilung 3a, pp. 183-221. (Engelmann: Leipzig).
- Brown, R. (1810). "Prodromus Florae Novae Hollandiae". (J. Johnson & Co.: London).
- Burbidge, N.T. (1955). "An index to the microfilm of Robert Brown's botanical descriptions (Manuscript) of Australian plants held by the British Museum (Natural History)". (C.S.I.R.O.: Canberra).
- Burbidge, N.T. (1956). Robert Brown's Australian collecting localities. *Proc. Linn. Soc. New S. Wales* 80: 229-233.
- Cain, A.J. & G.A. Harrison (1958). An analysis of the taxonomist's judgement of affinity. *Proc. Zool. Soc. London* 131: 85-98.
- Cantino, P.D. (1982). Affinities of the Lamiales: A cladistic analysis. *Syst. Bot.* 7: 237-248.
- Carrick, J. (1976). Studies in Australian Lamiaceae 1. Genus *Wrixonia* F. Muell. (Prostantheroideae). *J. Adelaide Bot. Gard.* 1: 27-34.
- Carrick, J. (1977). Studies in Australian Lamiaceae 2. *Eichlerago* a new genus allied to *Prostanthera*. *J. Adelaide Bot. Gard.* 1: 115-122.
- Cheng, Y.S. & E. von Rudloff (1970). The volatile oil of the leaves of *Chamaecyparis nootkatensis*. *Phytochemistry* 9: 2517-2527.
- Churchill, D.M., T.B. Muir & D.M. Sinkora (1978). The published works of Ferdinand J.H. Mueller (1825-1896). *Muelleria* 4: 1-120.
- Clifford, H.T. & W. Stephenson (1975). "An introduction to numerical classification". (Academic Press: New York).
- Clifford, H.T. & W.T. Williams (1973). Classificatory dendrograms and their interpretation. *Austral. J. Bot.* 21: 151-162.
- Cochrane, G.R., B.A. Fuhrer, E.R. Rotherham & J.H. Willis (1968). "Australian flora in colour. Flowers and plants of Victoria". (A.H. & A.W. Reed: Sydney).
- Conn. B.J. (1980). A taxonomic revision of *Geniostoma* subg. *Geniostoma* (Loganiaceae). *Blumea* 26: 245-364.

- Conn, B.J. (1982). "A taxonomic revision of *Prostanthera* Labill. section *Klanderia* (F. v. Muell.) Benth. (Labiatae)". (Unpubl. Ph. D. dissertation. Univ. of Adelaide, South Australia).
- Copley, P.B. (1982). A taxonomic revision of the genus *Ixodia* (Asteraceae). *J. Adelaide Bot. Gard.* 6: 41-54.
- Corner, E.J.H. (1976). "The seeds of dicotyledons". 2 vols. (Cambridge Univ. Press: Cambridge).
- Cramér, H. (1946). "Mathematical methods of statistics". (Princeton Univ. Press: Princeton).
- Cronquist, A. (1968). "The evolution and classification of flowering plants". (Thomas Nelson & Sons: London).
- Cronquist, A. (1981). "An integrated system of flowering plants". (Columbia Univ. Press: New York).
- Cunningham, G.M., W.E. Mulham, P.L. Milthorpe & J.H. Leigh (1982). "Plants of western New South Wales". (D. West, Govt Printer: Sydney).
- Currey, J.E.B. (Ed.) (1966). "Reflection on the colony of New South Wales. George Caley". (Angus & Robertson: London).
- Dagnelie, P. (1966). A propos des différentes méthodes de classification numérique. *Rev. Statist. Appl.* 14: 55-75.
- Davis, P.H. & V.H. Heywood (1963). "Principles of Angiosperm taxonomy". (Oliver & Boyd: Edinburgh).
- Ehrlich, P.R. & P.H. Raven (1965). Butterflies and plants: a study in coevolution. *Evolution* 18: 586-608.
- Emboden, W.A. Jr & H. Lewis (1967). Terpenes as taxonomic characters in *Salvia* section *Audibertia*. *Brittonia* 19: 152-160.
- Ewart, A.J. (1930). "Flora of Victoria". (Govt Printer: [Melbourne]).
- Faegri, K. & L. van der Pijl (1979). "The principles of pollination ecology". 3rd ed. (Pergamon Press: London).
- Farris, J.S. (1966). Estimation of conservatism of characters by constancy within biological populations. *Evolution* 20: 587-591.
- Farris, J.S. (1977). On the phenetic approach to vertebrate classification. In Hecht, M.K., B.M. Hecht & P.C. Goody (Eds), "Major patterns in Vertebrate evolution", pp. 823-850. (Plenum Press: New York).
- Field, B. (Ed.) (1825). "Geographical memoirs on New South Wales; by various hands:". pp. 332 & 333. (John Murray: London).
- Firmage, D.H. & R. Irving (1979). Effect of development on monoterpene composition of *Hedeoma drummondii*. *Phytochemistry* 18: 1827-1829.
- Fisher, F.J.F. (1968). The role of geographical and ecological studies in taxonomy. In Heywood, V.H. (Ed.), "Modern methods in plant taxonomy". (Academic Press: London).
- Florek, K., J. Łukasiewicz, J. Perkal, H. Steinhaus & S. Zubrzycki (1951a). Sur la liaison et la division des points d'un ensemble fini. *Colloquium Math.* 2: 282-285.
- Florek, K., J. Łukasiewicz, J. Perkal, H. Steinhaus & S. Zubrzycki (1951b). Taksonomia Wrocławska. *Przegl. Antropol.* 17: 193-211.
- Ford, H.A. & D.C. Paton (1976). The value of insects and nectar to honeyeaters. *Emu* 76: 83 & 84.
- Ford, H.A., D.C. Paton & N. Forde (1979). Birds as pollinators of Australian plants. *New Zealand J. Bot.* 17: 509-519.
- Forss, D.A. & G.L. Holloway (1967). Recovery of volatile compounds from Butter oil. *J. Amer. Oil Chemists Soc.* 44: 572-575.
- Fraenkel, G.S. (1959). The raison d'être of secondary plant substances. *Science* 129: 1466-1470.
- Gardner, C.A. (1931). "Enumeratio plantarum Australiae occidentalis". (Govt Printer: Perth).
- Gentili, J. (1972). "Australian climate patterns". (Nelson: Melbourne).
- Gottsberger, G. (1971). Colour changes of petals in *Malvaviscus arboreus* flowers. *Acta Bot. Neerl.* 20: 381-388.
- Gould, S.J. & R.F. Johnston (1972). Geographic variation. *Annu. Rev. Ecol. Syst.* 3: 457-498.
- Gower, J.C. (1966). Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* 53: 325-338.
- Gower, J.C. (1967). Multivariate analysis and multidimensional geometry. *Statistician* 17: 13-28.
- Gower, J.C. (1969). A survey of numerical methods useful in taxonomy. *Acaralugia* 11: 357-375.
- Grant, K.A. & V. Grant (1968). "Hummingbirds and their flowers". (Columbia Univ. Press: New York).
- Green, J.W. (1980). A revised terminology for the spore-containing parts of anthers. *New Phytol.* 84: 401-406.
- Haegi, L. (1981). Labiatae (Lamiaceae). In Jessop, J. *et al.* (Eds), "Flora of Central Australia". (Austral. Syst. Bot. Soc., A.H. & A.W. Reed: Sydney).
- Hagemer, E.M. (1958). Inapplicability of the subspecies concept to North American Marten. *Syst. Zool.* 7: 1-7.
- Hallé, F., R.A.A. Oldeman & P.B. Tomlinson (1978). "Tropical trees and forests. An architectural analysis". (Springer-Verlag: Berlin).
- Hanover, J.W. (1966a). Environmental variation in the monoterpenes of *Pinus monticola* Dougl. *Phytochemistry* 5: 713-717.
- Hanover, J.W. (1966b). Genetics of terpenes. I. Gene control of monoterpene levels in *Pinus monticola* Dougl. *Heredity* 21: 73-84.
- Harborne, J.B. (Ed.) (1972). "Phytochemical ecology". (Academic Press: London).
- Harborne, J.B. (1977). "Introduction to ecological biochemistry". (Academic Press: London).
- Harborne, J.B. (Ed.) (1978). "Biochemical aspects of plant and animal coevolution". (Academic Press: London).
- Hefendehl, F.W. & M.J. Murray (1972). Changes in monoterpene composition in *Mentha aquatica* produced by gene substitution. *Phytochemistry* 11: 189-195.
- Hellyer, R.O., E.V. Lassak, H.H.G. McKern & J.L. Willis (1969). Chemical variation within *Eucalyptus dives*. *Phytochemistry* 8: 1513 & 1514.
- Hickey, M. & C.J. King (1981). "100 families of flowering plants". (Cambridge Univ. Press: Cambridge).

- Hill, R.S. (1980). A numerical taxonomic approach to the study of angiosperm leaves. *Bot. Gaz.* 141: 213-229.
- Hill, R.S. (1981). A stopping rule for partitioning dendrograms. *Bot. Gaz.* 141: 321-324.
- Hills, H.G., N.H. Williams & C.H. Dodson (1972). Floral fragrances and isolating mechanisms in the genus *Catasetum* (Orchidaceae). *Biotropica* 4: 61-76.
- Hillson, C.J. (1959). Comparative studies of floral morphology of the Labiatae. *Amer. J. Bot.* 46: 451-459.
- Holman, R.T. & W.H. Heimerman (1973). Identification of components of orchid fragrances by gas chromatography mass spectrometry. *Amer. Orchid Soc. Bull.* 42: 678-682.
- Holmgren, P.K., W. Keuken & E.K. Schofield (1981). Index herbariorum. Part 1. The herbaria of the world, ed. 7, *Reg. Veg.* 106: 1-452.
- Huck, R.B. (1981). Evolutionary patterns in *Dicerandra* (Labiatae). *Austral. Syst. Bot. Soc. Newsletter* 28: 33 & 34.
- Hummel, K. & K. Staesche (1962). Die Verbreitung der Haartypen in den natürlichen Verwandtschaftsgruppen. *Handbuch der Pflanzenanatomie* Band IV, Teil 5: 207-292.
- Hunt, R.S. & E. von Rudloff (1974). Chemosystematic studies in the genus *Abies*. I. Leaf and twig oil analysis of alpine and balsam firs. *Can. J. Bot.* 52: 477-487.
- Hutchinson, J. (1969). "Evolution and phylogeny of flowering plants". (Academic Press: London).
- Jacobs, S.W.L. & J. Pickard (1981). "Plants of New South Wales". (D. West, Govt Printer: Sydney).
- Jardine, N. (1969). A logical basis for biological classification. *Syst. Zool.* 18: 37-52.
- Jessop, J.P. (1980). Australian Lamiaceae. *Austral. Plants* 10 (83): 299-308.
- Johns, R.K. (1961). "Geology and mineral resources of southern Eyre Peninsula". Department of Mines. Bull. 37 (Govt Printer: Adelaide).
- Johnson, L.A.S. (1976). Problems of species and genera in *Eucalyptus* (Myrtaceae). *Plant Syst. Evol.* 125: 155-167.
- Johnson, L.A.S. & B.G. Briggs (1975). On the Proteaceae—the evolution and classification of a southern family. *J. Linn. Soc., London, Bot.* 70: 83-182.
- Johnson, R.W. (1982). Effect of weighting and the size of the attribute set in numerical classification. *Austral. J. Bot.* 30: 161-174.
- Junell, S. (1934). Zur Gynäceummorphologie und Systematik der Verbenaceen und Labiaten. *Sym. Bot. Upsalienses* 4: 1-29.
- Keighery, G.J. (1980). Bird pollination in south Western Australia: A checklist. *Plant Syst. Evol.* 135: 171-176.
- Knoll, F. (1956). "Die Biologie der Blüte". (Springer-Verlag: Berlin).
- Krumbein, W.C. (1962). The computer in geology. *Science* 136: 1087-1092.
- Labillardière, J.J.H. de (1806). "Novae Hollandiae plantarum specimen". Vol. 2. (Huzard: Paris).
- Lampert, R.J. (1981). "The Great Kartan mystery". (Dept. Prehistory Austral. Natl. Univ.: Canberra).
- Lance, G.N. & W.T. Williams (1967). A general theory of classificatory sorting strategies. I. Hierarchical systems. *Comput. J.* 9: 373-380.
- Langenheim, J.H. (1969). Amber: a botanical inquiry. *Science* 163: 1157-1169.
- Langenheim, J.H. (1981). Variation in terpenoid resins: implications for insect herbivory in the tropics. In "XIII International Botanical Congress, Abstracts". (Austral. Acad. Sci.: Sydney).
- Lassak, E.V. (1980). New essential oils from the Australian flora. The volatile oils of the genus *Prostanthera* (Lamiaceae) and of *Kippisia suaeifolia* (Asteraceae). (Unpubl. talk presented to 8th International Congress of Essential Oils, Cannes, 12-17 October, 1980).
- Laut, P., P.C. Hegligers, G. Keig, E. Löffler, C. Margules, R.M. Scott & M.E. Sullivan (1977a). "Environments of South Australia. Province 2 Murray Mallee". (Land Use Research. C.S.I.R.O.: Canberra).
- Laut, P., P.C. Hegligers, G. Keig, E. Löffler, C. Margules, R.M. Scott & M.E. Sullivan (1977b). "Environments of South Australia. Province 3 Mt Lofty Block". (Land Use Research. C.S.I.R.O.: Canberra).
- Laut, P., P.C. Hegligers, G. Keig, E. Löffler, C. Margules, R.M. Scott & M.E. Sullivan (1977c). "Environments of South Australia. Province 4 Eyre and Yorke Peninsulas". (Land Use Research. C.S.I.R.O.: Canberra).
- Laut, P., P.C. Hegligers, G. Keig, E. Löffler, C. Margules, R.M. Scott & M.E. Sullivan (1977d). "Environments of South Australia. Province 7 Western Pastoral". (Land Use Research. C.S.I.R.O.: Canberra).
- Lawrence, G.H.M. (1955). "An introduction to plant taxonomy". (MacMillan: New York).
- Leenhouts, P.W. (1968). A guide to the practice of herbarium taxonomy. *Reg. Veg.* 58: 1-60.
- Leichhardt, L. (1847). "Journal of an overland expedition in Australia, . . .". (T. & W. Boone: London).
- Leigh, J., J. Briggs & W. Hartley (1981). "Rare or threatened Australian plants". Austral. Natl Parks & Wildlife Serv. Special Publ. 7. (Commonwealth of Australia: [Canberra]).
- Lindley, J. (1829-1830). "Edward's botanical register: or, ornamental flower-garden and shrubbery". Vol. 15 [new series vol 2], tt. 1282, 1289 [pp. 1 & 2], 1292 [pp. 2 & 3], 1300 [p. 2]. (James Ridgeway: London).
- Maarse, H. & R.E. Kepner (1970). Changes in composition of volatile terpenes in Douglas fir needles during maturation. *J. Agric. & Food Chem.* 18: 1095-1101.
- Marcus, L.F. & J.H. Vandermeer (1966). Regional trends in geographic variations. *Syst. Zool.* 15: 1-14.
- Mayr, E. (1969). "Principles of systematic zoology". (McGraw-Hill: New York).
- McGillivray, D.J. (1973). Michel Gandoger's names of Australian plants. *Contr. New S. Wales Nat. Herb.* 4: 319-365.
- McNeil, J. (1978). Purposeful phenetics. *Syst. Zool.* 28: 465-482.
- McQuinn, W.G. (1970). "Allan Cunningham. Botanist and explorer". (Melbourne Univ. Press: Carlton).
- Meissner, L.P. & E.I. Organick (1980). "Fortran 77: featuring structured programming". (Addison-Wesley: Reading, Massachusetts).

- Melchior, H. (1964). Labiatae. In "A. Engler's Syllabus der Pflanzenfamilien". Ed. 12 vol. 2, pp. 438-444. (Borntraeger: Berlin).
- Mitchell, T.L. (1848). "Journal of an expedition into the interior of tropical Australia, . . .". (Longman, Brown, Green & Longmans: London).
- Moore, C. (1893). Labiatae. In "Handbook of the Flora of New South Wales". (C. Potter, Govt Printer: Sydney).
- Mueller, F. [J.H. von] (1855). Definition of rare or hitherto undescribed Australian plants, chiefly collected within the boundaries of the colony of Victoria. *Trans. Phil. Soc. Victoria* 1: 48.
- Mueller, F. [J.H. von] (1868). *Fragmenta phytographiae Australiae*. Vol. 6, p. 108. Melbourne.
- Mueller, F. [J.H.] von (1875). *Fragmenta phytographiae Australiae*. Vol. 9, p. 162. Melbourne.
- Mueller, F. [J.H.] von (1882). "Systematic Census of Australian plants". (M'Carron, Bird & Co. for Victorian Govt: Melbourne).
- Muller, C.H. (1966). The role of chemical inhibition (allelopathy) in vegetation composition. *Bull. Torrey Bot. Club* 9: 332-351.
- Munir, A.A. (1978). Taxonomic revision of Chloanthaceae trib. Physopsidae. *Brunonia* 1: 407-692.
- Munir, A.A. (1979). Taxonomic revision of genus *Pityrodia* (Chloanthaceae). *J. Adelaide Bot. Gard.* 2: 1-138.
- Nelson, E.C. (1981). Phytogeography of southern Australia. In Keast, A. (Ed.), "Ecological Biogeography of Australia". (W. Junk bv: The Hague).
- Nicholas, H.J. (1973). Terpenes. In Miller, L.P. (Ed.), "Phytochemistry. Volume II Organic metabolites". pp. 254-309. (Van Nostrand Reinhold: New York), pp. 254-309.
- Nie, N.H., C.H. Hull, J.C. Jenkins, K. Steinbrenner & D.H. Bent (1975). "Statistical Package for Social Sciences". 2nd ed. (McGraw-Hill Book Co.: New York).
- Oh, H.K., T. Sakai, M.B. Jones & W.M. Longhurst (1967). Effects of various essential oils located from Douglas fir needles upon sheep and deer rumen microbial activity. *Appl. Microbiol.* 15: 777-784.
- Paton, D.C. & H.A. Ford (1977). Pollination by birds of native plants in South Australia. *Emu* 77: 73-85.
- Penfold, A.R. & J.L. Willis (1961). "The Eucalypts". World Crop Series (Leonard Hill: London, & Interscience Publ.: New York).
- Pijl, L. van der (1972). Functional considerations and observations on the flowers of some Labiatae. *Blumea* 20: 93-103.
- Porter, D.M., R.W. Kiger & J.E. Monahan (1973). "A guide for contributors to the flora of North America. Part II. An outline and glossary of terms for morphological and habitat description (provisional ed.)". (Smithsonian Institution: Washington, D.C.).
- Powell, R.A. & R.P. Adams (1973). Seasonal variation in the volatile terpenoids of *Juniperus scopulorum* (Cupressaceae). *Amer. J. Bot.* 60: 1041-1050.
- Pridham, J.B. (Ed.) (1967). "Terpenoids in plants". (Academic Press: New York).
- Proctor, M. & P. Yeo (1973). "The pollination of flowers". (Collins: London).
- Pyke, G.H. (1980). The foraging behaviour of Australian honeyeaters: a review and some comparisons with hummingbirds. *Austral. J. Ecol.* 5: 343-369.
- Ratkowsky, D.A. & G.N. Lance (1978). A criterion for determining the number of groups in a classification. *Austral. Comput. J.* 10: 115-117.
- Raven, P.H. (1972). Why are bird-visited flowers predominately red? *Evolution* 26: 674.
- Raven, P.H. (1974). Nomenclature proposals to the Leningrad congress. I. Proposals for the simplification of infraspecific terminology. *Taxon* 23: 828-831.
- Reichenbach, H.G.L. (1828). "Conspectus regni vegetabilis". (Cnobloch: Leipzig).
- Roth, I. (1977). Fruits of Angiosperms. *Handbuch der Pflanzenanatomie* Band X, Teil 1: 1-675.
- Rudloff, E. von (1967). Chemosystematic studies in the genus *Picea* (Pinaceae). I. Introduction. *Can. J. Bot.* 45: 891-901.
- Rudloff, E. von (1972a). Chemosystematic studies in the genus *Pseudotsuga*. I. Leaf oil analysis of the coastal and Rocky Mountain varieties of the Douglas fir. *Can. J. Bot.* 50: 1025-1040.
- Rudloff, E. von (1972b). Seasonal variation in the composition of the volatile oil of the leaves, buds, and twigs of white spruce (*Picea glauca*). *Can. J. Bot.* 50: 1595-1603.
- Rudloff, E. von (1973). Geographical variation in the terpene composition of the leaf oil of Douglas fir. *Pure & Applied Chem.* 34: 401-410.
- Rudloff, E. von (1975). Volatile leaf oil analysis in chemosystematic studies of North American conifers. *Biochem. Syst. Ecol.* 2: 131-167.
- Runeckles, V.C. & T.J. Mabry (Eds) (1973). "Terpenoids. Structure, biogenetics and distribution". (Academic Press: New York).
- Sandermann, H. (1962). Terpenoids: Structure and distribution. In Florin, M. & O.H.S. Mason (Eds), "Comparative biochemistry, Volume III". pp. 503-630. (Academic Press: New York).
- Sandland, R.L. & P.C. Young (1979). Probabilistic tests and stopping rules associated with heirarchical classification techniques. *Austral. J. Ecol.* 4: 399-406.
- Schmid, R. (1972). A resolution of the *Eugenia-Syzygium* controversy (Myrtaceae). *Amer. J. Bot.* 59: 423-436.
- Schodde, R., B. Glover, F.C. Kinsky, S. Marchant, A.R. McGill & S.A. Parher (1978). Recommended English names for Australian birds. *Emu Suppl.* 77: 245-307.
- Sharma, M. & V. Singh (1982). Morphology of the gynoeceum in Labiatae. *Blumea* 28: 61-75.
- Smith, P.M. (1976). "The chemotaxonomy of plants". (Edward Arnold: London).

- Sneath, P.H.A. (1957). The application of computers to taxonomy. *J. Gen. Microbiol.* 17: 201-226.
- Sneath, P.H.A. (1964). Mathematics and classification from Adanson to the present. In Lawrence, G.H. (Ed.), "Adanson: The bicentennial of Michael Adanson's "Familles de Plantes"". pp. 471-498. (Univ. of Pittsburgh Press: Pittsburgh).
- Sneath, P.H.A. & R.R. Sokal (1973). "Numerical taxonomy". (W.H. Freeman: San Francisco).
- Sokal, R.R. (1965). Statistical methods in systematics. *Biol. Rev.* 40: 337-391.
- Sokal, R.R. & R.C. Rinkel (1963). Geographic variation of the alate *Phemphigua populi-transversus* in eastern North America. *Univ. Kansas Sci. Bull.* 44: 467-507.
- Sokal, R.R. & F.J. Rohlf (1969). "Biometry". (W.H. Freeman: San Francisco).
- Sokal, R.R. & P.H.A. Sneath (1963). "Principles of numerical taxonomy". (W.H. Freeman: San Francisco).
- Sondheimen, E. & J.B. Simeone (1970). "Chemical ecology". (Academic Press: New York).
- Southwell, I.A. (1973). Variation in the leaf oil of *Eucalyptus punctata*. *Phytochemistry* 12: 1341-1343.
- Specht, R.L. (1972). "The vegetation of South Australia". (Govt Printer: Adelaide).
- Stace, H.C.T., C.D. Hubble, R. Brewer, K.H. Northcote, J.R. Sleeman, M.J. Mulcahy & E.G. Hallsworth (1968). "A handbook of Australian soils". (Rellim Tech. Publ.: Glenside, South Australia).
- Stafleu, F.A. & R.S. Cowan (1976). Taxonomic literature. 2nd ed. Vol. I: A-G. *Reg. Veg.* 94: 1-1136.
- Stafleu, F.A. & R.S. Cowan (1979). Taxonomic literature. 2nd ed. Vol. II: H-Le. *Reg. Veg.* 98: 1-991.
- Stafleu, F.A. & R.S. Cowan (1981). Taxonomic literature. 2nd ed. Vol. III: Lh-O. *Reg. Veg.* 105: 1-980.
- Stafleu, F.A. *et al.* (Eds) (1978). International code of botanical nomenclature. *Reg. Veg.* 97.
- Stearn, W.T. (1960). Introduction to R. Brown's 'Prodromus Florae Novae Hollandiae'. In Brown R. "Prodromus Florae Novae Hollandiae et Insulae Van Diemen (1810) and Supplement Primum (1830)". pp. vlii. Facsimile ed. (Engelmann: Weinheim).
- Stearn, W.T. (1973). "Botanical latin". 2nd ed. (David & Charles: Newton Abbott, Great Britain).
- Stephenson, W., W.T. Williams & S. Cook (1974). The macrobenthos of soft bottoms in southern Moreton Bay (south of Peel Island). *Mem. Queensl. Mus.* 17: 73-124.
- Stopp, K. (1950a). Karpologische Studien I & II. *Abh. Akad. Wiss. Lit. Mainz, Math.-Nat. Kl.* 7: 165-218.
- Stopp, K. (1950b). Karpologische Studien III & IV. *Abh. Akad. Wiss. Lit. Mainz, Math.-Nat. Kl.* 17: 495-542.
- Thien, L.B., W.H. Heimermann & R.T. Holman (1975). Floral odors and quantitative taxonomy of *Magnolia* and *Liriodendron*. *Taxon* 24: 557-568.
- Thorne, R.F. (1976). A phylogenetic classification of the Angiospermae. In Hecht, M.K., W.C. Steere & B. Wallace (Eds), *Evolutionary Biol.* 9: 35-106.
- Toelken, H.R. (1981). The species of *Crassula* L. in Australia. *J. Adelaide Bot. Gard.* 3: 57-90.
- Troll, W. (1964). "Die Infloreszenzen. Typologie und Stellung im Aufbau des Vegetationskörpers, 1. I Deskriptive Morphologie des Infloreszenzen; II Typologie der Infloreszenzen". (Jena: Gustav Fischer).
- Troll, W. (1969). "Die Infloreszenzen. Typologie und Stellung im Aufbau des Vegetationskörpers, 2. III Monotele Synfloreszenzen". (Jena: Gustav Fischer).
- Turner, B.L. (1970). Molecular approaches to population problems at the infraspecific level. In Harborne, J.B. (Ed.), "Phytochemical phylogeny". pp. 187-205. (Academic Press: New York).
- Tutin, T.G., V.H. Heywood, N.A. Burges, D.H. Valentine, S.M. Walters & D.A. Webb (1964). Introduction. In "Flora Europaea". Vol. 1, p. xx. (Cambridge Univ. Press: Cambridge).
- Twidale, C.R. (1968). "Geomorphology". (Nelson: Melbourne).
- Uphof, J.C. Th. (1962). Plant hairs. *Handbuch der Pflanzenanatomie* Band IV, Teil 5: 1-206.
- Weberling, F. (1965). Typology of inflorescences. *J. Linn. Soc. (Bot.)* 59: 215-221.
- Weberling, F. (1981). "Morphologie der Blüten und der Blütenstände". (Eugen Ulmer: Stuttgart).
- Weberling, F. (1982). Current problems of modern inflorescence morphology. In Conn, B.J. (Ed.), "Inflorescence morphology". *Austral. Syst. Bot. Soc. Newsletter* 30: 5-21.
- Weimarek, G. (1972). On "Numerical chemotaxonomy". *Taxon* 21: 615-619.
- Whiffin, T. (1977). Volatile oils and the study of natural hybridization between *Correa aemula* and *C. reflexa* (Rutaceae). *Austral. J. Bot.* 25: 291-298.
- Whiffin, T. (1978). Geographic variation in tropical tree species. In Tomlinson, P.B. & M.H. Zimmermann (Eds), "Tropical trees as living systems". pp. 31-54. (Cambridge Univ. Press: Massachusetts).
- Whiffin, T. (1981). Analysis of hybridization between *Eucalyptus pauciflora* Sieber ex Spreng. and *E. radiata* Sieber ex DC (Myrtaceae). *Bot. J. Linn. Soc.* 83: 237-250.
- Whiffin, T. (1982a). Variation and evolution in the genus *Flindersia* (Rutaceae). II Review of methods for geographic variation analysis of volatile oil data. *Austral. J. Bot.* 30: 645-657.
- Whiffin, T. (1982b). Numerical analysis of volatile oil data in systematic studies of Australian rainforest trees. *Taxon* 31: 204-210.
- White, C.T. (1944). Contribution to the Queensland flora, No. 8. *Proc. Roy. Soc. Queensl.* 55: 74.
- Williams, W.T. (1971). Principles of clustering. *Annu. Rev. Ecol. Syst.* 2: 303-326.
- Williams, W.T. (Ed.) (1976). "Pattern analysis in agricultural sciences". (C.S.I.R.O. Elsevier: Amsterdam).
- Williams, W.T., M.B. Dale & G.N. Lance (1971). Two outstanding ordination problems. *Austral. J. Bot.* 19: 251-258.
- Williams, W.T. & P. Gillard (1971). Pattern analysis of a grazing experiment. *Austral. J. Agric. Res.* 22: 245-260.
- Williams, W.T. & W. Stephenson (1973). The analysis of three-dimensional data (sites x species x time) in marine ecology. *J. Exp. Mar. Biol. Ecol.* 11: 207-227.

- Willis, J.H. (1973). "A handbook to plants in Victoria. Volume II Dicotyledons". (Melbourne Univ. Press: Carlton).
- Winkler, H. (1939). Versuch eines "natürlich" Systems der Früchte. *Beitr. Biol. Pflanzen* 26: 201-220.
- Winkler, H. (1940). Zur Einigung und Weiterführung in der Frage des Fruchtsystems. *Beitr. Biol. Pflanzen* 27: 92-130.
- Wojciechowska, B. (1958). Taxonomy, morphology and anatomy of fruits and seeds in the genus *Salvia* L. *Monographiae Botanicae* 6: 3-56.
- Wojciechowska, B. (1961a). Fruits of the middle european species of the genus *Prunella* L. (fam. Labiatae), their morphology and anatomy. *Monographiae Botanicae* 12: 49-88.
- Wojciechowska, B. (1961b). Fruits of the middle european species of the subfamily Stachyoideae (fam. Labiatae). *Monographiae Botanicae* 12: 89-120.
- Wojciechowska, B. (1966). Morphologie und Anatomie der Früchte und Samen aus der Familie der Labiatae mit besonderer Berücksichtigung der Arzneipflanzen. *Monographiae Botanicae* 21: 3-244.
- Womble, W.H. (1951). Differential systematics. *Science* 114: 315-322.
- Zavarin, E., W.B. Critchfield & K. Snajberk (1969). Turpentine composition of *Pinus contorta* x *Pinus banksiana* hybrids and hybrid derivatives. *Can. J. Bot.* 47: 1443-1453.
- Zavarin, E., L. Lawrence & M.C. Thomas (1971). Compositional variation of leaf monoterpenes in *Cupressus macrocarpa*, *C. pygmaea*, *C. goveniana*, *C. abramsiana* and *C. sargentii*. *Phytochemistry* 10: 379-393.
- Zavarin, E. & K. Snajberk (1973). Geographic variability of monoterpenes from cortex of *Pseudotsuga menziesii*. *Pure & Applied Chem.* 34: 411-434.